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Preventive Approaches to Stormwater Management

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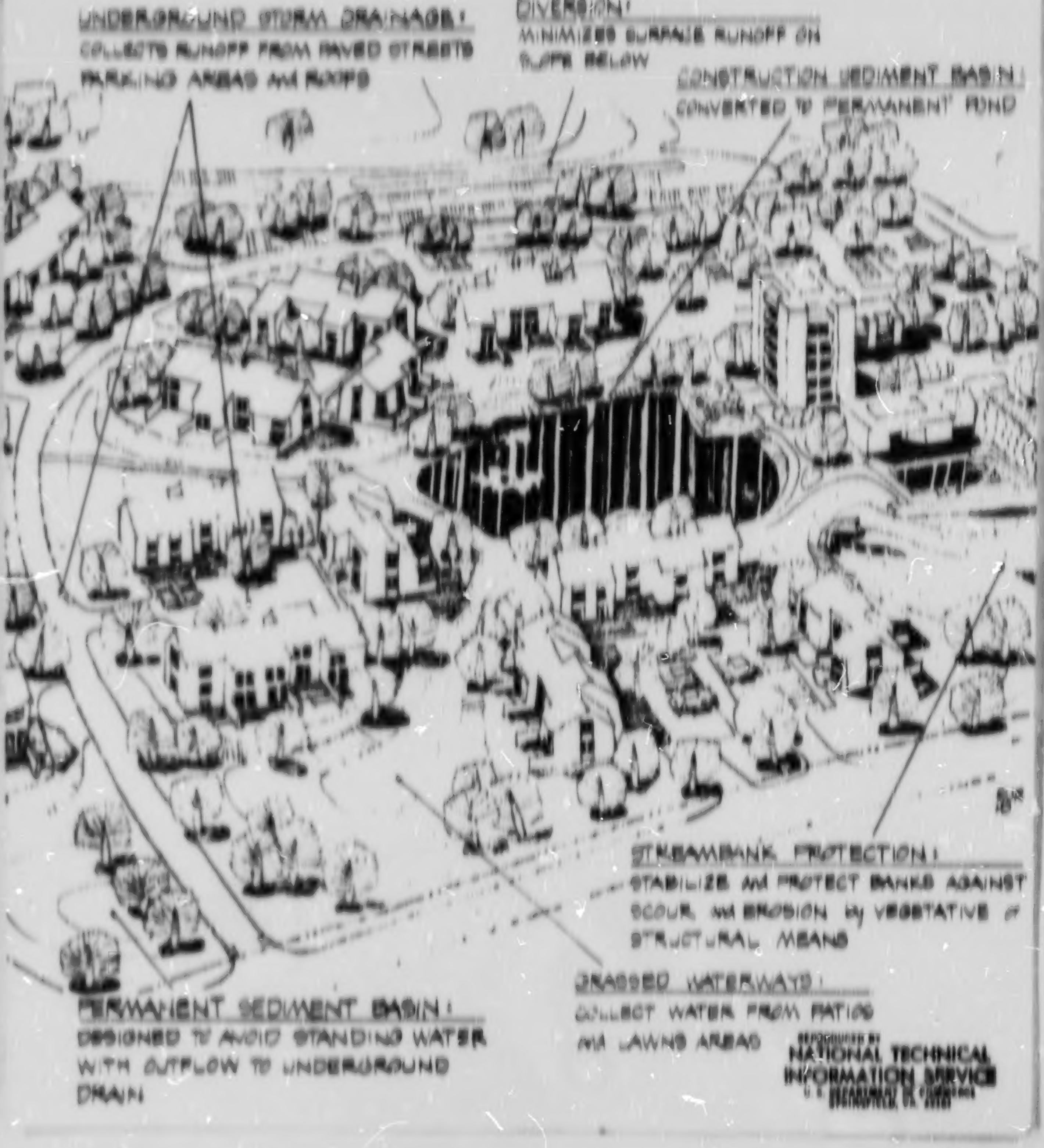
Preventive Approaches to Stormwater Management


UNDERGROUND STORM DRAINAGE:
COLLECTS RUNOFF FROM PAVED STREETS PARKING AREAS and ROOFS
DIVERSION:
MINIMIZES SURFACE RUNOFF ON SLOPE BELOW
CONSTRUCTION SEDIMENT BASIN:
CONVERTED TO PERMANENT POND
STREAMBANK PROTECTION:
STABILIZE and PROTECT BANKS AGAINST SCOUR and EROSION by VEGETATIVE or STRUCTURAL MEANS
GRASSED WATERWAYS:
COLLECT WATER FROM PATIOS and LAWNS AREAS
PERMANENT SEDIMENT BASIN:
DESIGNED TO AVOID STANDING WATER WITH OUTFLOW TO UNDERGROUND DRAIN

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This report is issued under section 304(e)(2) of Public Law 92-500, and was prepared to support implementation of sections 208 (b)(2)(A),(B), and (C) of the Act. Section 304(e)(2) provides:

> The Administrator, after consultation with appropriate Federal and State agencies and other interested persons, shall issue to appropriate Federal agencies, the States, water pollution control agencies, and agencies designated under section 208 of this Act, within one year after the effective date of this subsection (and from time to time thereafter) information including (1) guidelines for identifying and evaluating the nature and extent of nonpoint sources of pollutants, and (2) processes, procedures, and methods to control pollution resulting from—
>
> "(A) agricultural and silvicultural activities, including runoff from fields and crop and forest lands;
>
> "(B) mining activities, including runoff and siltation from new, currently operating, and abandoned surface and underground mines;
>
> "(C) all construction activity, including runoff from the facilities resulting from such construction;
>
> "(D) the disposal of pollutants in wells or in subsurface excavations;
>
> "(E) salt water intrusion resulting from reductions of fresh water flow from any cause, including extraction of ground water, irrigation, obstruction, and diversion; and
>
> "(F) changes in the movement, flow or circulation of any navigable waters or ground waters, including changes caused by the construction of dams, levees, channels, causeways, or flow diversion facilities.

Sections 208(b)(2)(A), (B), and (C) provide:

> "(b)(1) Not later than one year after the date of any designation of any organization under subsection (a) of this section such organization shall have in operation a continuing areawide waste treatment management planning process consistent with section 201 of this Act. Plans prepared in accordance with this process shall contain alternatives for waste treatment management, and be applicable to all wastes generated within the area involved. The initial plan prepared in accordance with such process shall be certified by the Governor and submitted to the Administrator not later than two years after the planning process is in operation.
>
> "(2) Any plan prepared under such process shall include, but not be limited to—
>
> "(A) the identification of treatment works necessary to meet the anticipated municipal and industrial waste treatment needs of the area over a twenty-year period, annually updated (including an analysis of alternative waste treatment systems), including any requirements for the acquisition of land for treatment purposes; the necessary waste water collection and urban storm water runoff systems; and a program to provide the necessary financial arrangements for the development of such treatment works;
>
> "(B) the establishment of construction priorities for such treatment works and time schedules for the initiation and completion of all treatment works;
>
> "(C) the establishment of a regulatory program to—
>
> "(i) implement the waste treatment management requirements of section 201(c),
>
> "(ii) regulate the location, modification, and construction of any facilities within such area which may result in any discharge in such area, and
>
> "(iii) assure that any industrial or commercial wastes discharged into any treatment works in such area meet applicable pretreatment requirements; ..."

This publication is one of several issued to support implementation of section 208 of Public Law 92-500 concerning the control of water pollution from urban runoff and other associated nonpoint sources of pollution. Other reports include: "Areawide Assessment Procedures Manual" Volumes I and II, EPA 600/9-76-014, July 1976 and "Proceedings - Urban Stormwater Management Seminars", WPD 03-76-04, January 1976, NTIS PB260889.

This document was prepared for use by local agency administrators, and others who may be involved in programs to abate pollution from urban runoff. The concept of source control (BMP) has been discussed in the past, this report lists many techniques that would be included in a Best Management Practice. The problems associated with implementing these practices, legal, financial, and institutional are also discussed.

The objective of this study was to provide a basic understanding to local administrators on what BMP is and those techniques which would comprise a BMP.

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SUBJECT: "Preventive Approaches To Stormwater Management"

FROM: Edmund Notzon, Acting Director
Water Planning Division

TO: All Regional Water Division Directors
All Regional 208 Coordinators

Technical Guidance Memorandum: TECH 30

Purpose

This document has been prepared to assist local governmental officials and 208 Agency Administrators in identifying methods of control for urban stormwater pollution.

Guidance

The enclosed report describes management techniques that should be considered when evaluating stormwater control alternatives. It includes suggested regulatory approaches, financial considerations, and institutional arrangements with a case study.

Enclosure

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EPA 440/9-77-001

PREVENTIVE APPROACHES TO STORMWATER MANAGEMENT

Contract No. 68-01-1945

January 1977

Project Officer
Dennis N. Athayde
Water Planning Division
Office of Water Planning & Standards
Washington, D.C. 20460

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The efforts described in this report were performed for the Nonpoint Source Branch of the Water Planning Division of EPA under Contract No. 68-01-1945. The work was performed under the direction of Mr. John Willson of Abt Associates Inc. Abt personnel contributing to this project were:

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The U. S. Environmental Protection Agency has reviewed this report and approved its publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency.

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1.0 INTRODUCTION

This manual is designed to help local planners, administrators, and elected officials meet their responsibilities regarding management of urban stormwater runoff under the 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500). The U.S. Environmental Protection Agency believes that stormwater runoff is a problem of increasing severity, which must be dealt with in urban and developing areas alike. The approach suggested in this manual is to minimize the adverse water quality impacts of runoff through a system of source controls. Source controls stress the reduction and prevention of runoff pollution before it ever reaches a collection system or receiving waters. Source control is the central tenet of the various management methods recommended in the manual--so-called Best Management Practices or BMPs. These BMPs are intended to help Section 208 areawide and other water quality planners adequately address the stormwater management problems prevalent in their particular locality.

The manual is intended to serve as a companion volume to a separate EPA study of techniques for data collection, analysis, and evaluation of alternative approaches to urban stormwater management.[1] That volume presents a simplified approach to an initial evaluation of the overall stormwater situation in a specific urban area, and of the costs and impacts of a variety of alternative solutions. In contrast, this manual is designed to introduce the nature of the stormwater problem to concerned officials and suggest preventive approaches, including a discussion of the legal, financial, and institutional issues which must be addressed if these preventive approaches are to be implemented.

Because the stormwater pollution problem has only recently received systematic attention and, further, because source control technologies are still under investigation, much work remains to be done. Source control, however, promises to be a workable, effective, and relatively inexpensive means of pollution abatement, according to available evidence.[2] EPA policy specifically delegates responsibility for refinement and implementation of Best Management Practices to designated areawide agencies and the states. The preventive approaches suggested in this manual are intended to help state and local officials begin this task. It remains to them to adapt and tailor these approaches to suit their own specific requirements for local implementation.

1.1 Urban Runoff as a Source of Water Pollution

Within the past twenty years, it has been recognized that waters discharged from separate storm sewers contain pollutants. Urban runoff pollution is the result of precipitation washing the surface of the city. Rain falling on an urban area picks up pollutants from the air; dusty roads, littered and dirty streets, and sidewalks; traffic by-products such as tar residuals, and vehicular exhaust products; galvanic corrosion particulates; and chemicals applied for fertilization, control of ice, rodents, insects, and weeds.

The ultimate cause of this pollution may be traced to the activities of man, and five sources may be readily identified. First, due to the effect of gravity, dust and other particulate matter falls on the urban environment or is washed from the air by rainfall. Winds carry dust and dirt into and away from an area, but leave large amounts trapped within the urban environment. Second, the residual products of automobiles, trucks, and buses remain a major source of suspended solids, chemical oxygen-demanding material, and heavy metals, especially lead. Third, the debris which results from man's carelessness litters the streets and is a major source of organic material, which is discharged into the receiving waters by urban stormwater runoff. Fourth, runoff from urban construction sites, whether from new private development or public work projects, contributes significant amounts of sediment. Fifth, and finally, illegal industrial, commercial and domestic hook-ups to storm sewers contribute a number of specific pollutants, e.g., used motor oil.

Polluted runoff contains substantial amounts of organic material, inorganic solids, and coliform bacteria. Other pollutants include nutrients, pesticides, and heavy metals. Clearly, these pollutants degrade the receiving water quality. This degradation often results in decreased dissolved oxygen level and high turbidity. Coliform bacteria indicates the presence of pathogenic bacteria which are pollutants. Moreover, nutrients in the form of nitrogen and phosphorus contribute to increased eutrophication rates. Although runoff contains pesticides and heavy metals, their impact on aquatic environment is yet largely unknown, though recent evidence suggests that the presence of heavy metals decreases the diversity of aquatic biota.

The direct effects of runoff upon water quality are manifold. Unregulated or poorly regulated runoff accelerates the erosion of land areas [illegible] stream banks and, in addition, causes deposition of sediments in channels. Moreover, increased flooding and increased potential for public health problems result from unregulated runoff along with a deterioration of aesthetic quality. Indeed, the total pollutant loads of storm water during runoff periods can exceed by many times that of municipal treatment plants. This condition could very well preclude meeting 1983 water quality standards, regardless of the degree of treatment afforded dry weather waste water flows.

Today, given the realities of industrialization, urbanization, and population increase, it is evident that environmental control is a critical factor. Wise use and control of water resources is necessary. If these water resources are to be protected, the problem of the urban environment must be dealt with. As a small part of that larger problem, stormwater runoff represents a significant source of water pollution. The urban environment collects the debris from man's activities, and precipitation flushes it through the collection system we have designed and discharges it into the receiving waters.

1.2 Best Management Practices for Urban Runoff Sources of Water Pollution

The object of source control is to protect the beneficial uses intended for receiving waters. While collection of runoff treatment appears as a possible means to achieve this end, its cost remains prohibitive. A less costly alternative is a preventive approach, designed to address the sources and causes of pollution. Best Management Practices seek to achieve this goal, i.e., reduction and prevention of pollution.

BMPs may be divided into two categories: those most useful for already built-up or developed areas and those applicable to new or developing areas. The problems of developed areas occur where structures and pavements are in place and where drainage is accomplished primarily through sewering. In densely populated commercial and industrial areas, management techniques such as improved sanitation and sewer maintenance practices are probably most effective. Such techniques reduce the amount of pollutants that can enter the drainage system.

The preventive concept best applies to developing urban areas, for these are areas where man's encroachment is more subject to control and drainage is essentially natural. These areas offer the greatest flexibility of approach in preventing pollution. What is required is to manage the expected development in such a way as to maintain a runoff regime as close to natural levels as possible. It is in these new areas where proper management practices can help prevent long-term problems, and hence, the reason for this manual's concentration upon managing the runoff problems associated with the urbanizing process.

Many of the BMP's are based on the concept of flow attenuation. Flow attenuation, in a hydrologic sense, means to increase the time of concentration and decrease the magnitude of the peak runoff. Less erosion results because reduced runoff velocity reduces the erosive force. Also, with this approach, large volumes of water are not allowed to rapidly accumulate at constrictions but flow at reduced rates over a longer period of time, thus diminishing the possibilities of localized flooding. The improvement in water quality results from reduced pollutant loadings being conveyed to the receiving stream.

Best Management Practices are an integrated approach incorporating both source and collection system controls. Source management deals with pollutants where they accumulate, before they are washed into the receiving waters. Collection system management begins with the ground surface and ends with the sewer outfall. As a planner looks to his own particular area to implement a program for stormwater management, a number of different management practices or techniques may suggest themselves. The object of Best Management Practices is to choose from among the combinations of technical alternatives designed to address the specific problems of the local area those which for legal, financial, or institutional reasons could most reasonably be implemented. Those combinations would be the Best Management Practices for that area.

According to EPA policy, Section 208 of the Federal Water Pollution Control Act Amendments of 1972 is intended to be the planning mechanism for the development of Best Management Practices to control urban stormwater runoff pollution. By definition, stormwater runoff discharges may be either point or nonpoint sources, or combinations of the two. (40 CFR 124, 125 (41 FR 11303 - 11307)) In the regulation promulgated by the Environmental Protection Agency, separate storm sewers located in an urban area and primarily operated for the purpose of collecting and conveying stormwater runoff come under the National Pollutant Discharge Elimination System as point sources. It is provided, however, that the EPA Administrator or the appropriate Regional Administrator may designate as a significant contributor of pollution any discharge of pollutants into navigable waters from a stormwater runoff conveyance, even though it is not located in an urban area; in this event, such a conveyance would come under the regulation. At this stage, the proposed regulations authorize discharges from separate storm sewers subject to: (1) any future regulations which EPA might issue, and (2) the right of the permitting authority to require individual storm sewered dischargers to apply for conventional NPDES permits.

1.3 Objectives and Organization of the Manual

This manual is intended to help local officials answer the following general questions:

(1) How does the process of urban development alter the natural hydrologic cycle and cause stormwater runoff pollution?

(2) What specific physical control measures are available under a preventive approach to stormwater management, and how are they implemented?

(3) What is the range of available regulatory instruments for controlling runoff pollution? Can these be implemented under existing powers or does their exercise require new authority? What legal issues, if any, does their use raise?

(4) What financing needs do preventive approaches entail, and how best can these be met?

(5) To what extent can existing institutional arrangements for stormwater management be successfully adapted to implement Best Management Practices? How can the needed coordination between and among levels of government best be achieved?

Although these questions are raised in the manual, detailed answers in terms of technique efficiencies, cost requirements, and effectiveness evaluations are beyond the scope of this volume. If one word describes the nature of the stormwater runoff problem, that word is "variability." Each community must look to the problems indigenous to its particular area and then select the Best Management Practices which apply. For this reason, the manual can suggest important relationships and introduce the range of issues that should be considered for stormwater management, but it cannot preempt the local planning needed to deal with the specific water quality and related land use problems inherent to the particular stormwater runoff situation. The central theme of the BMP concept is that each area must provide for itself the means of control for stormwater runoff which have been tailored to suit its specific requirements and which are capable of being implemented by local governments.

The manual is organised so that the reader may quickly refer to just those problems or issues with which he is particularly concerned.

Chapter 2 provides a brief overview of the hydrologic cycle, the determinants of an area's runoff characteristics, the water quality activities, and the special runoff problems presented by certain environmentally sensitive lands.

Chapter 3 presents, in modular fashion, descriptions of a series of specific physical control measures which can be applied by private developers and local governments to prevent runoff pollution. As appropriate, implementation mechanisms are described and successful local examples provided.

Chapter 4 discusses the available regulatory approaches for preventive stormwater management, their relationship to the legal structure of local government powers, and legal issues surrounding their use. Again, local examples of their application are supplied.

Chapter 5 provides a brief discussion of financial issues, and considerations. It covers funding needs, available funding sources, and the problems involved in putting needs and sources together.

Chapter 6 focuses on the critical institutional problem affecting implementation of preventive approaches, that of securing the needed intergovernmental coordination.

A separate bibliography is provided at the back of this volume.

The various chapters do not necessarily have to be read in order. Each is meant to stand alone, although an effort has been made to interrelate them at a number of key points. The initial chapter on Hydrology and Urbanization (Chapter 2) is intended primarily for nontechnical readers and thus may be skipped entirely by those persons who already have an adequate understanding of the relationship between urban development and water quality.

REFERENCES

1. For a recent survey of this literature, the reader is referred to Richard Field and Donna Knowles, "Urban Runoff and Combined Sewer Overflow," Journal of the Water Pollution Control Federation, Vol. 47, No. 6, June 1975, pp. 1352-1369.

2. EPA Contract No., with Hydroscience, Inc., Walnut Creek, California (in progress).

2.0 HYDROLOGY AND URBANIZATION

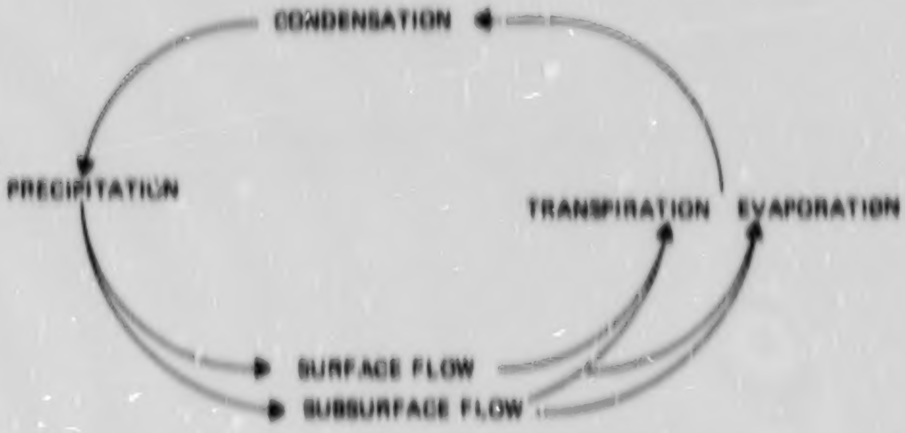
The purpose of this chapter is to provide the nontechnical reader with the basic principles of urban hydrology which are needed to understand the subsequent discussions of preventive approaches to stormwater managment. It briefly describes the hydrologic cycle, particularly surface and subsurface flows. The natural determinants of these flows are identified, then the impacts of the urban development process upon them are explained. Development-induced changes in runoff characteristics are then linked to the specific water quality problems they cause or exacerbate. Finally, special attention is devoted to the need to protect certain environmentally sensitive lands from intensive development because of potentially serious water quality (and other natural system) impacts of runoff.

2.1 Natural Determinants of Runoff

The Hydrologic Cycle

The hydrologic cycle refers to the cycle which takes water from the ocean or land surfaces by evaporation, transports it by winds across large distances during which condensation occurs, and deposits the water on the earth's surfaces in the form of precipitation (rain, snow, etc.). Once there, the water gravitates downward toward lower levels, everything being discharged into the ocean or being returned to the atmosphere by evaporation and transpiration. The hydrologic cycle is shown schematically in Figure 2.1. Especially important to remember is that the individual processes within this cycle do not occur sequentially, but concurrently, being supplied with energy from the sun and gravitational forces.

Figure 2.1: The Hydrologic Cycle



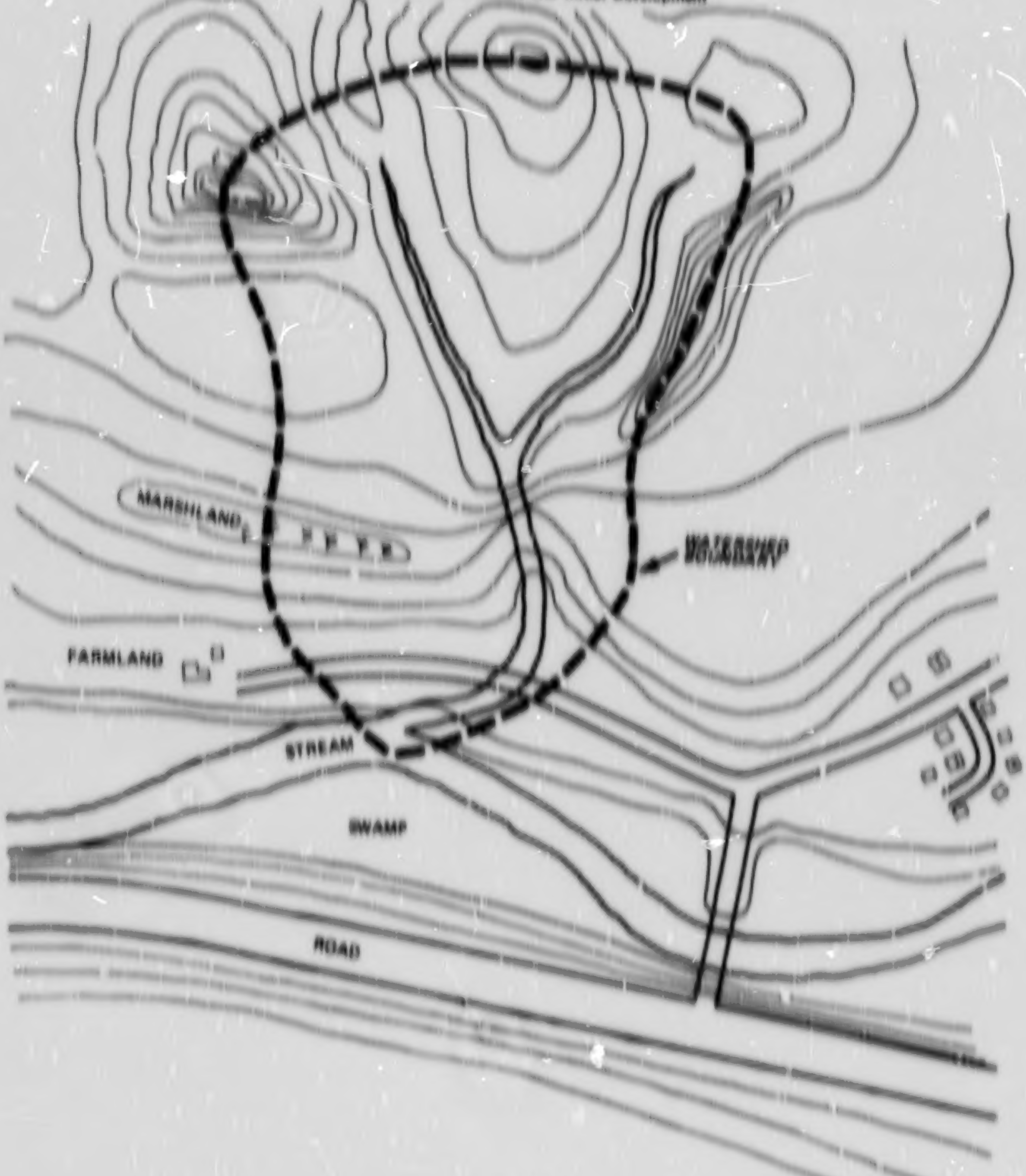
For ease of presentation, the impacts of both natural and man-made forces on this cycle can be discussed at the level of the individual *watershed*. A watershed is an area bounded by higher elevations, draining ultimately to a single low point at which one can measure the total flow from that area for a given rainfall. Figure 2.2 depicts a watershed characterized by typical land types which affect runoff from storms: upland bogs, aquifer recharge areas, semi-permeable soils, marshland, farmland, swampland, rivers, and impermeable surfaces (roads). Figure 2.3 shows a cross-section of this same watershed. The stage of development illustrated in both figures represents initial urbanization--the change of land toward more intensive uses by humans.

Variables Associated with Precipitation

Precipitation, measured in inches, varies in form, intensity, and duration. The *form* may be described as rain or snow; the significance of the differentiation is that the accumulation of snow can result in a high runoff potential during a rapid melting period. The forecast of snow melt and runoff is not dealt with here, being a specialized area of interest. The *intensity* of rainfall, as measured in inches per minute, reflects the rate of potential accumulation of water at the earth's surface over a short period of time. The *duration* of the precipitation is the time over which the rainfall occurs. By knowing the intensity and duration of the rainfall, and the area of the watershed over which it fell, one can determine the maximum quantity of water which could flow out of that watershed.

For a rainfall of a given intensity and duration, a *hydrograph* for a watershed can be determined. Figure 2.4 presents a hydrograph which could exist for the watershed illustrated previously, showing the quantity of surface and subsurface flow at a given time that the given rainfall would produce. A more intense rainfall of the same duration would produce a hydrograph with a proportionately higher peak, reflecting greater total and peak runoff volume (see Figure 2.5). A rainfall of an amount equal to that in Figure 2.5 but of lesser intensity, and thus longer duration, would produce still a different hydrograph, this one with the peak shifted to the right (see Figure 2.6).

Figure 2.2
Example of Watershed, Showing
Natural Contours and Initial Development


MARSHLAND
WATERSHED BOUNDARY
FARMLAND
STREAM
SWAMP
ROAD

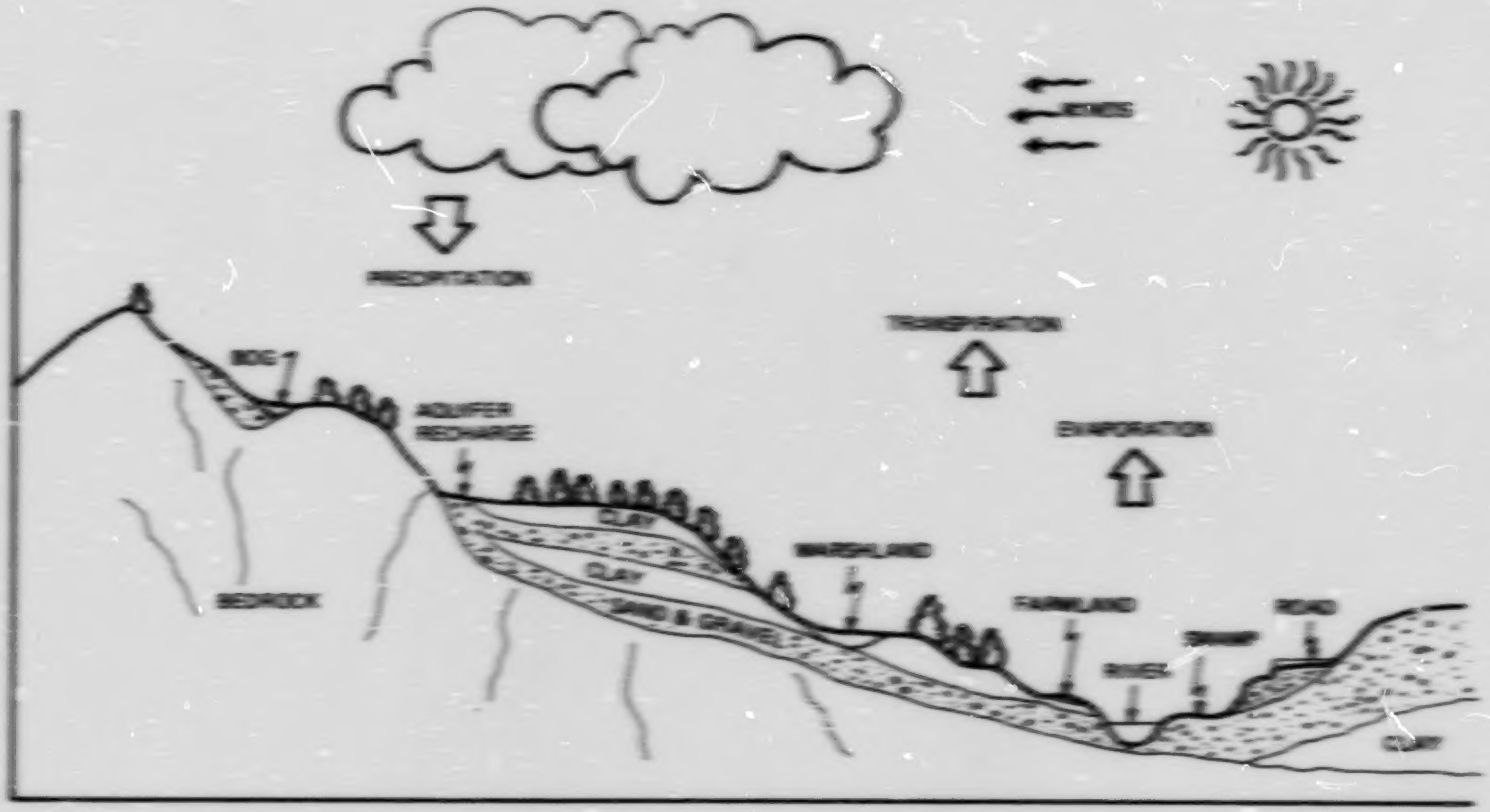

WINDS
PRECIPITATION
TRANSPIRATION
EVAPORATION
BOG
AQUIFER RECHARGE
CLAY
CLAY
SAND & GRAVEL
BEDROCK
MARSHLAND
FARMLAND
RIVER
SWAMP
ROAD
CLAY

Figure 2.3
Cross-Section of Land Showing
Typical Factors Affecting Runoff

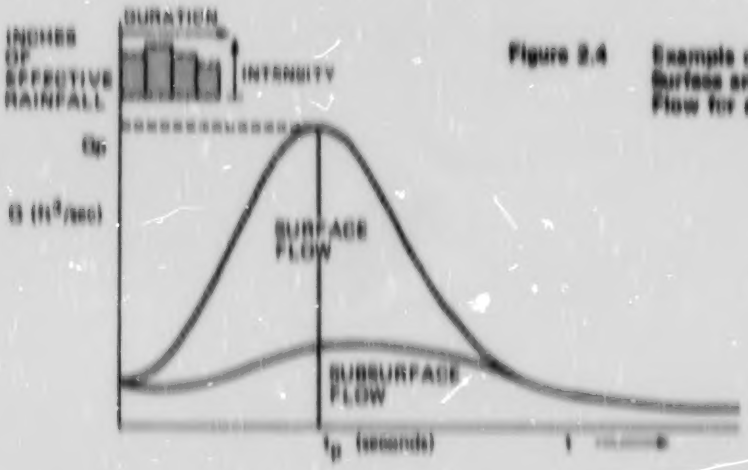


Figure 2.4 Example of Hydrograph Showing Surface and Subsurface Stream Flow for a Given Rainfall

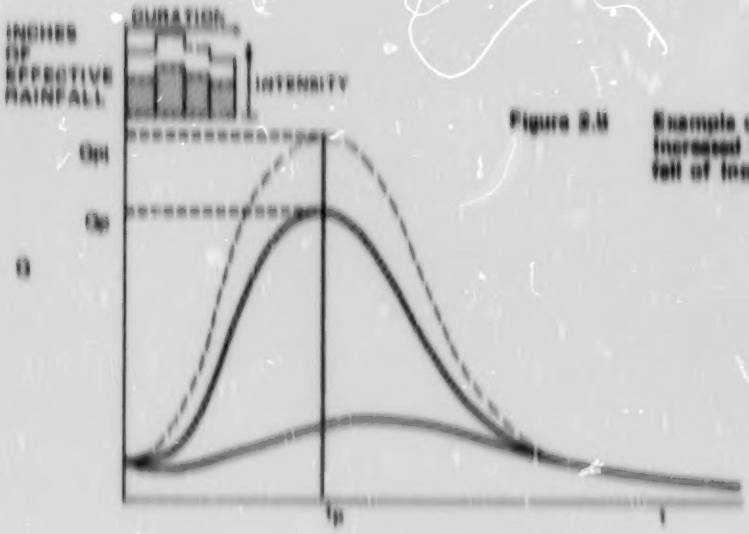


Figure 2.5 Example of Hydrograph Showing Increased Peak Flow from a Rainfall of Increased Intensity

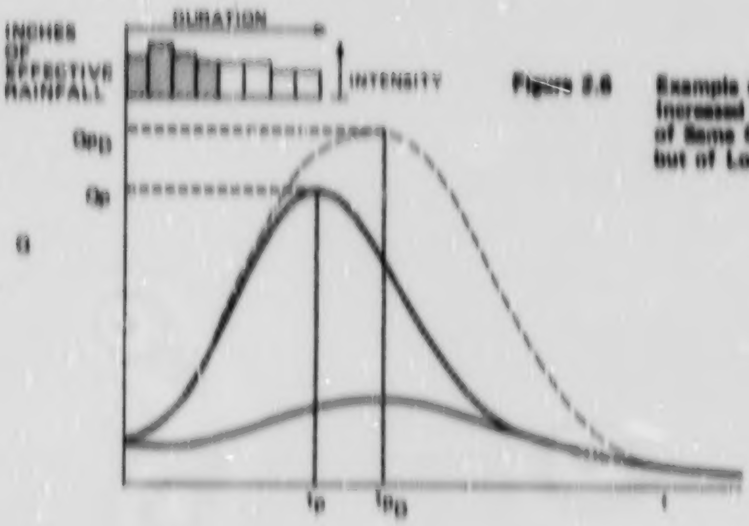


Figure 2.6 Example of Hydrograph Showing Increased Flow from a Rainfall of Same Quantity (as Figure 2.5) but of Longer Duration

Each watershed has its own unique hydrograph relating total and peak runoff to time for a given rainfall. This is reflected in its *unit hydrograph*, that hydrograph resulting from one inch of direct runoff from a storm of specified duration.[1] Construction of a unit hydrograph for a particular watershed permits one to develop probable hydrographs for many different types of storms and their resulting runoffs.[2] However, any change in the natural factors which affect runoff will change the hydrograph for that watershed.

Variables Associated with the Natural Environment

The amount and rate at which water gravitates from the point it hits the earth to another point is determined not only by the duration and intensity of the rainfall but also by the characteristics of the surface across which it has to flow. These factors can be grouped into those affecting infiltration and those affecting velocity. Together these factors determine the rate of flow (velocity) and the percentage of rainfall which infiltrates into the ground, and thereby does not become an immediate part of the runoff.

Infiltration will depend upon the porosity of the surface and the length of time the water is able to stand on that surface and seep into the soil. Infiltration is facilitated by the presence of bogs, swampland, marshes, and surface depressions which have poor drainage. The rate at which water permeates into the soil is determined by the soil type itself, unless soil density changes. For example, "packing down" of the soil or the paving of the surface decreases infiltration. Subsurface flow, in terms of the hydrograph, is significant due to the extended time it takes for this quantity of water to flow out of the watershed. A decrease in subsurface flow will result in a larger quantity of runoff in a shorter period of time.

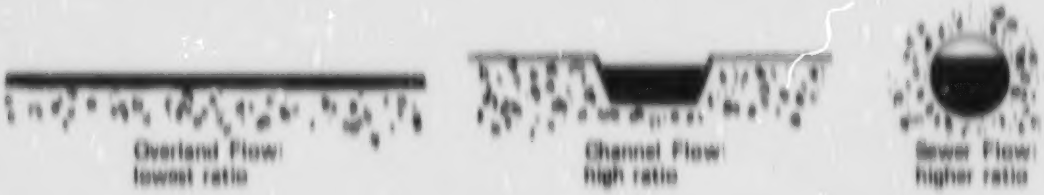
Velocity is the distance the flow travels in a certain time period. It is usually measured in feet per second (fps). Velocity is reflected in the hydrograph in both the vertical and horizontal axes. The vertical axis is the quantity of water (Q), measured in cubic feet per second (cfs), that traverses a given point in the watershed at a certain time. The quantity of flow (Q) by the point of measurement is equal to the result of the cross-sectional area (A) through which that flow occurs times the rate of flow or velocity (V): $Q = AV$. The horizontal axis or the hydrograph is time (t). As such, it measures the time it takes for water to gravitate through the watershed. Therefore, any changes in the factors that affect the time it takes to pass through the watershed affect both the quantity of flow and the velocity.

The factors which affect velocity for a given flow can be grouped under the following headings:

- the extent of the surface over which the flow has to occur
- the slope down which the flow occurs
- the roughness of the surface over which the flow occurs.

The effect of the extent of the surface area on runoff flow will vary with the type of flow. In shallow "overland" flow the runoff occurs in a very thin flow over a large surface, whether it be pavement or forestland. In shallow overland flow the ratio of the cross-sectional area of runoff to the surface which it "wets" during the runoff is very small.[3] The containment of flow, as by "channel" flow or "storm sewer" flow, effectively reduces the surface area wetted by the flow to those surfaces which contain that flow. The largest ratio of cross-section of flow to surface affected by that flow occurs when a nearly full pipe is reached. The larger the ratio, the higher the velocity of flow.[4]

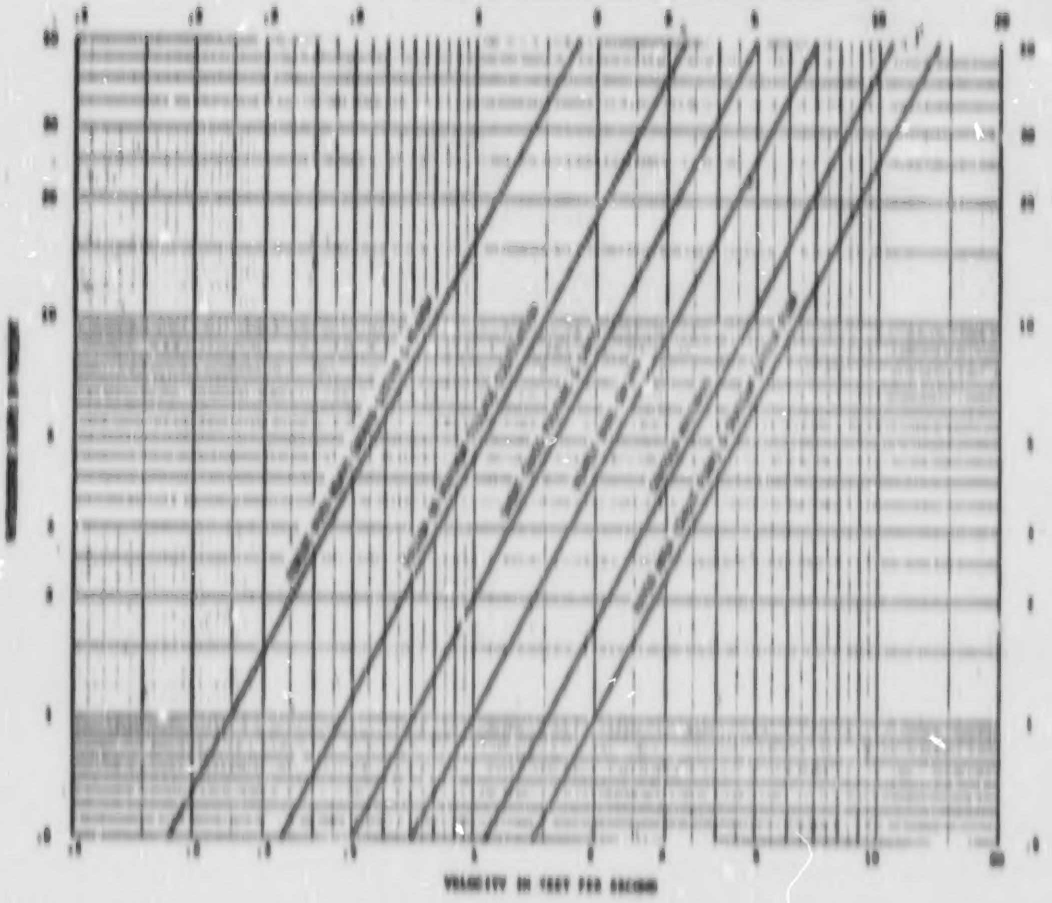
Figure 2.7: Ratio of Cross-Sectional Area to Surface Wetted, by Type of Flow


Overland Flow: lowest ratio
Channel Flow: high ratio
Sewer Flow: higher ratio

The effect of slope on runoff flow is such that, for any type of flow, the velocity of the runoff increases with an increase in slope. For flow confined to channel flow or sewer flow, the velocity varies directly as the square root of the slope.[5]

The effect of the roughness of the surface on runoff is inversely proportional to the measure of the extent of the roughness; a decrease in the roughness will increase the velocity. For shallow overland flow, the interrelationship between slope and surface roughness (as represented by forms of vegetation) and the resulting effect on velocity is shown in Figure 2.8, a graphical

Figure 2.8: Average Velocities for Estimating Travel Time for Shallow Overland Flow



representation. For example, for a given 2% of slope, the runoff velocity (fps) increases from .3 (for forest with heavy ground litter and meadow) to .66 (for fallow or minimum tillage cultivation) to 2.75 (for paved area).

For contained flows, such as channels and sewers, a coefficient of roughness has been derived for various surfaces.[6] This means that the confinement of a stream to a smooth metal pipe (having a coefficient of 0.010), from a previously very weedy and sluggish natural channel (having a coefficient of 0.112) may have effectively increased the velocity by ten times in the case of this example.

A summary of the factors which affect the runoff characteristics of a watershed is shown in the following figure, Figure 2.9. Channelization, which is usually thought of as a man-made process associated with urbanization, is also a natural factor affecting infiltration and surface runoff. Channelization often occurs in large streams during flood stages, as a result of the velocity and quantity of flood waters; it can readily be seen in relatively flat terrain where the ox-bow bends of former rivers have been left behind. During flooding the torrent of the flow cuts across these bows, thereby straightening out the streams and permitting a larger volume of water to flow over a shorter distance. After the flood recedes, usually a new meander or bow is formed due to the natural forces.

2.6 The Runoff Impacts of Urbanization

The urbanization process often results in physical alteration of the environment. Many of these changes result in immediate benefits, including increased densities and the use of the property under a wide range of environmental conditions, including intense and prolonged precipitation. However, such development brings about changes in those factors which determine an area's runoff characteristics and thereby affects the hydrologic cycle. Inappropriate or unregulated development can also lead to secondary effects on other parts of the environment. For example, a decrease in infiltration because of extensive surface paving can result in lowering of the water table, thereby killing trees which carry

Figure 2.9: Factors Which Affect Runoff Characteristics

Physical Factors	Impact of Factor on Runoff Characteristics
Soil Porosity	Infiltration is affected by actions which change the imperviousness of the soil; such actions include soil composition and surface pavement, thereby reducing infiltration
Drainage	Infiltration is assisted by drainage which retains runoff, thereby providing additional time for the water to infiltrate. Bogs, swamps and other surface areas provide temporary retention areas, thereby providing increased infiltration times and a reduction in the peak flows of small runoffs.
Infiltration	Both velocity and quantity of runoff determine amount of water which can be infiltrated; a reduction in either of these factors increases the potential amount of water which will infiltrate into the ground
Channelization	The velocity of water being drained from the area is a function of the distance over which it has to travel, the surface bed, and the size of the channel: by creating a channel which shortens the distance and reduces the surface roughness, one facilitates an increased velocity. The quantity of runoff is increased by an increase in the effective cross-sectional area of the channel.
Slope	The velocity of the runoff is directly related to the slope of the watercourse, as demonstrated in the Manning equation (velocity is a function of the square root of the slope). Any increase in the slope will therefore increase the velocity of the runoff from the area.
Surface Roughness	The velocity of water running off an area is inversely proportional to the coefficient of roughness associated with the surface
Velocity	The quantity of water which can run off from an area is a function of the velocity of the runoff (and therefore of all those factors which affect velocity) and the cross-sectional area through which the runoff can occur.

out the transpiration of vapor to the atmosphere. The destruction of these trees permits the sun to heat the pavement, thereby increasing the ambient heat and making the local environment a "heat island." Preventive approaches seek to minimize changes in the natural hydrograph of an area and reduce or eliminate such secondary environmental effects.

The usual result of the urbanization of an area, whether it be a large-scale development in a short period of time or an equally large development over several years, is a change in all the factors which affect runoff:

- a decrease in soil porosity through compaction
- an elimination of surface areas which retain precipitation
- an increase in impermeable surfaces
- a construction of channels and storm sewers to carry off the excess surface water
- an increase in site slopes due to terracing
- a decrease in vegetation (trees, grasses, shrubs, etc.), thereby decreasing transpiration and interception
- an increase in the smoothness of surfaces

Often one change can have an effect on several of the factors which affect infiltration and the characteristics of the runoff. For example, the paving of a surface reduces permeability of the surface, reduces vegetation, and reduces infiltration, thereby increasing the quantity of runoff and the velocity of that runoff, while reducing the amount of water which will infiltrate into the ground for downstream flow augmentation.

The impact of the urbanization process in terms of the hydrograph is shown in Figure 2.10, which for ease of understanding is divided into three parts. However, in the natural process, these impacts occur together, for they are interrelated. It can be seen that the immediate quantity of the runoff is greater and that it occurs earlier. With the increase in runoff velocity, it takes less time for the water to concentrate and, therefore, a greater amount of runoff occurs earlier. This increased concentration of runoff is augmented by that quantity which is no longer able to permeate into the soil.

Figure 2. 10: Impact of Urbanization as Reflected in Changes of Hydrograph

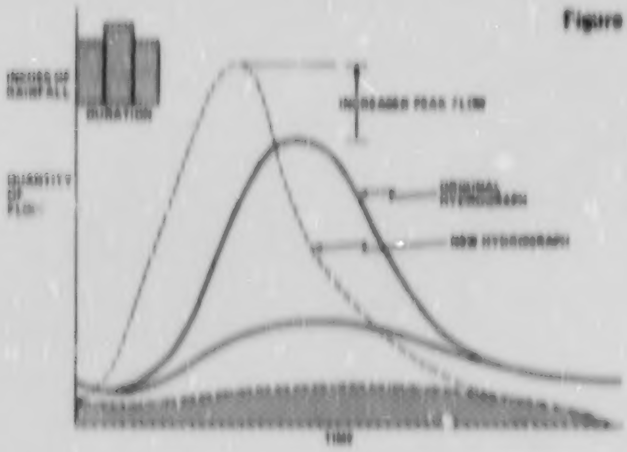


Figure 2. 10a. Impact: Increased Peak Flow

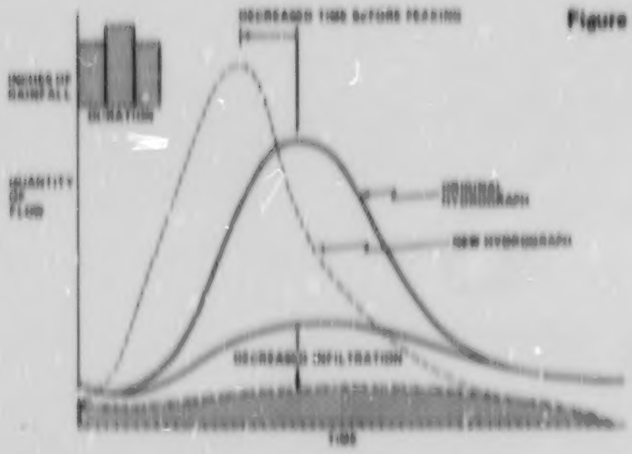


Figure 2. 10b. Impact: Decreased Time Before Peaking

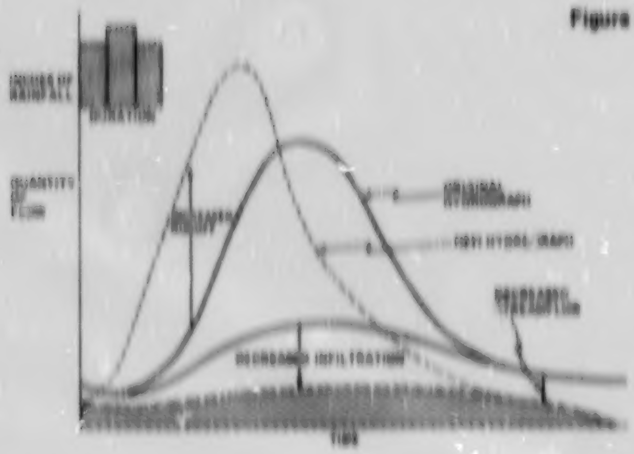


Figure 2. 10c Impact: Increased Peak Runoff

The impact of the urbanisation process on runoff may be seen using the typical home as an example. Prior to the purchase of the houselot for the home, assume the land use was a hay field (or a part of the forest, or an orchard). As such, it has a vegetative cover with a root system that provides a comparatively high rate of infiltration to the soil beneath. To construct this home, a series of events has to occur which can be expected to change not only the immediate site of the house, but also the area surrounding the site. The preparation of the site can include the removal of large trees, if any, which will interfere with the new home or equipment brought in to prepare the site; terracing of the site if the slope is sufficient to limit usefulness of household activities; and provision of a road or driveway as well as other utilities to the site. Therefore, preparation of the site entails surface and subsurface disruption of the vegetation and of the soil, resulting in the removal, exposure and compaction of the soil material. Such site preparation decreases the permeability of the soil.

The construction of the home on the site provides a roof which is impermeable. The rainfall runoff from this roof is carried away in gutters and drains which, in effect, is channelisation of runoff. The driveway or access road is usually paved, for ease of maintenance, and thereby provides additional impermeable surface. The runoff from this surface has to drain away to some other area, and is often channeled to the drainage provided for in the primary or secondary roadway.

The marginal impact of a single new home in any environment, rural or suburban, can usually be considered small or insignificant. However, the impact of many new homes is cumulative, and can often be considered large or significant. For example, a two-lane roadway may be able to serve a few homes, but the development of a large site with a number of homes may necessitate not only the improvement of the roadway serving the site, but also the widening of other roadways which handle traffic of the roadway serving the site.

Water supply and wastewater disposal needs for a limited number of homes on a particular site may be served adequately by wells and septic systems. However, at some relatively low density groundwater and soil conditions typically are such that the site can no longer handle the additional water supply and wastewater disposal demands. The potential impact on the hydrologic cycle from the elimination of the septic systems, which return water--however polluted--to the ground, and the export of wastewater via sewer pipes to a downstream treatment plan can be significant. Such action reduces groundwater flow and therefore the natural low-flow augmentation. If the development entails both a sewer system and a water supply system which imports water from outside the watershed, then the above impact is transferred to the watershed from which the water is being withdrawn.

These examples illustrate that the impact of the urbanization process on infiltration is not limited to the immediate site, but extends to all those areas which help provide services to that site. A solution often proposed to ameliorate the effects of the urbanization process is to decrease the densities at which the population lives. This is done by encouraging the population to "spread" out, thereby decreasing the concentration of those factors which affect the environment. However, in many cases this results in a decrease of the immediate concentration of the impacts but an increase in the overall impact and a significant deterioration to the environment in additional areas. The solutions which this manual addresses are those which recognize that there can be urban areas of varying densities, and that the impact which the urbanization process has on runoff from these areas will depend on wise use of preventive measures which have to be planned before, and initiated during, the development of the area.

2.3 Runoff Impacts and Water Quality Problems

The preceding sections have illustrated how urban development can lead to reduced infiltration, due to increased amounts of impervious surfaces, and increased runoff both in terms increased volume and higher velocity. These changes in an area's natural hydrologic balance can in turn lead to serious impacts on water quality. The two major water quality problems affected are

- erosion and sedimentation
- surface and subsurface pollution

These problems are briefly discussed in the paragraphs which follow.

Erosion and Sedimentation

The construction phase of urban development can result in significant alteration of the landscape, the extent of the changes usually depending upon the size of the development. A construction cost commonly incurred is large-scale removal of vegetative cover in order that construction can proceed smoothly and efficiently. The impact, in terms of the hydrograph, is increased runoff from the area resulting both from increased quantity and velocity of flow. Both of these factors lead to significant removal of soil through the erosion process. The actual amount worked away from the site will also depend upon the extent of surface area exposed to the runoff and the characteristics of the soil.[7]

In the United States it has been estimated that man-made activities remove nearly four billion tons annually from the land. Three billion tons of this sediment are deposited in flood plains, river channels, lakes and reservoirs, and the remainder is carried to the oceans.[8] The sediment washed from areas undergoing development involving new construction is from five to five hundred times as great as that from undeveloped rural areas. The consequences of erosion are loss of productive topsoil and the deposition of the soil, including its organic constituents in streams, marshes, lakes, and the various water bodies. The resulting impact on these water bodies is a smothering of streambed organisms and plants, destruction of their storage capacity for water supply and flood control, and an increase in the rate of eutrophication of lakes, swamps and other water bodies.

Sedimentation not only interferes with the functioning of the natural ecosystem, but also with the uses which mankind usually expects to make of these water bodies. Sedimentation of streams and rivers with a heavy organic load decreases their aeration capacity and the ability of the water to assimilate future waste loads imposed by discharges from wastewater treatment facilities. Furthermore, deposition of the sediment in reservoirs reduces the capacity of the reservoir for its intended use, whether it be water supply, power generation, or flood storage. In due time these dams will retain only silt and the original problem (water supply, power, and flood control) will still have to be solved. Sedimentation also interferes with the use of water bodies for recreational purposes. The destruction of bottom or bed life and the inflow of organic matter can result in a decrease of oxygen, thereby killing fish. Furthermore, the transport of sediment in streams and lakes reduces the aesthetic appeal of these waters, whether it be due to the dirty water or the resulting much on the bottom.

Studies of river channels have shown that the natural forces inherent in periodic flows naturally construct and maintain a channel with the capacity to carry a volume smaller than the average flood; this means that on the average such rivers will overflow their banks every 1.5 to 2 years. However, with runoffs of increasing volumes and velocity, the resulting impact in the short-term is flooding but in the long term is an increase in the channel's cross-sectional area through erosion of its banks. This, in turn, means additional deposits of sedimentation downstream.

Surface and Subsurface Pollution

The constituents of pollutants which are deposited on the surface of urban environments vary widely, ranging from common organic material to highly toxic metals. Some pollutants are intentionally placed on the surface, only to be carried away by the runoff, e.g. road salt, insecticides, herbicides. Others are the unintentional residue of man's activities, such as lead from automobile exhausts and oil dripping from trucks and cars. Such pollutants appear to vary according to the land use and intensity of land use.

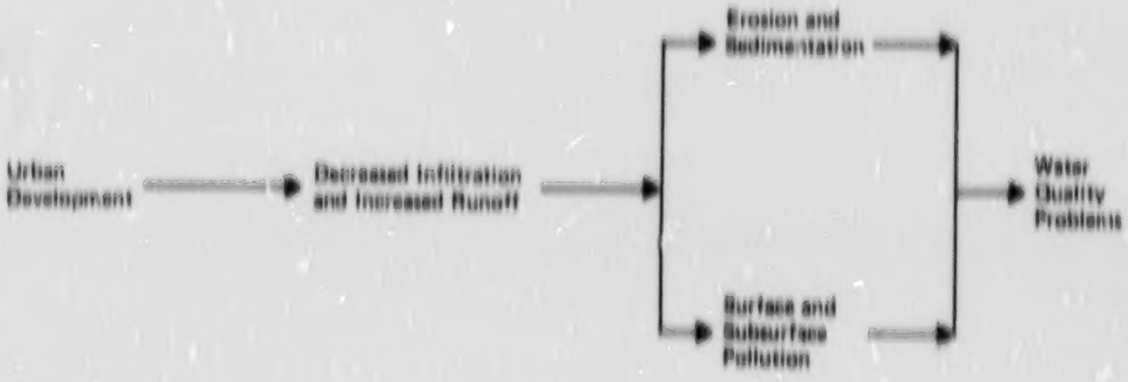
For a given frequency of rainfall, increasing urbanization leads to greater removal of these surface pollutants due to the increased quantity and velocity of the resulting runoff. This becomes important when one realizes that the most significant pollution occurs when there is just sufficient runoff to carry the pollutants from their place of deposition to the receiving waters; this runoff provides the least dilution in the streams. For the same frequency of rainfall occurrences, this means that the urbanization process will result more often in greater scouring or washing of the pollutants into the streams.

Leaching refers to the removal of soluble materials by percolating water. If these soluble materials are pollutants, this removal is harmful. Subsurface leachage occurs as an intended action in the draining of a septic tank. However, if a leaching field is blocked or otherwise fails, proper leaching does not occur and subsurface water containing pollutants often works its way to the surface. There it can be picked up by runoff and carried to nearby bodies of water, resulting in degradation of water quality.

Leaching often occurs at landfills, as rainfall percolates down through the site where wastes have been disposed. If water percolating through this waste picks up soluble materials, or harmful viruses and bacteria, and later becomes part of that groundwater which augments streamflow, these pollutants may also be carried into the stream. Proper landfill location and operation will serve to minimize leaching problems.

This completes the brief description of how urban development can lead to runoff-related water quality problems. The conceptual framework which it has presented (see Figure 2.11 below) will be used to organize the discussion of technical solutions provided in Chapter 3. More generally, it should help the nontechnical reader to understand the basis for the subsequent discussions of implementation approaches and strategy development.

Figure 2.11: Conceptual Framework for Preventive Approaches to Urban Stormwater Runoff


Urban Development
Decreased Infiltration and Increased Runoff
Erosion and Sedimentation
Surface and Subsurface Pollution
Water Quality Problems

2.4 Protection of Environmentally Sensitive Lands

This section takes up the planning context for protecting certain environmentally sensitive lands, those which play an important role either in protecting or, if improperly developed, in degrading ground and surface water quality. The basic planning considerations are the same, regardless of whether the regulatory approach used is to acquire the lands (or development rights) themselves or to restrict development to specified non-intensive uses.

The five land types discussed are:

- Streams and creekbeds
- Aquifers, and their recharge areas
- Wetlands
- Woodlands
- Steep slopes

Many of the natural processes associated with these land types make significant contributions to water quality. The direct costs to the public of failing to protect them can be high, and are associated with the need to provide storm sewers, higher levels of water and wastewater treatment, and new sources of water supply.[9]

2.4.1 Valuable Natural Processes

Streams and Creekbeds. Streams and creeks play two important roles within the hydrologic cycle. First, they provide major drainage systems carrying runoff and sediment from higher elevations to low-lying land and water bodies. Second, they contribute water to aquifers during the wet season and recieve groundwater through springs or seepage during the dry periods. Development in these areas, by removing vegetation and introducing impervious surfaces, increases erosion and sedimentation which in turn increases stream turbidity and reduces available oxygen in the water. The increased runoff introduces urban pollutants in the form of petroleum products, fertilizers, road salts, etc. Removal of shading vegetation can increase thermal pollution of the streams. Development also can adversely affect overall hydrologic balance within the watershed. Streambed siltation obstructs natural flows from surface to groundwater; stream flow becomes irregular, with lower base flows and higher peak flows, raising the level of flooding.

Aquifers. Groundwater is carried by aquifers, formations composed of consolidated (limestone, basalt) and unconsolidated (sand, gravels) rock. This underground water supply is fed by seepage from streams and lakes as well as by precipitation which percolates directly to the acquifer. Not only is groundwater an important source of water for human consumption, but it also helps regulate surface flow by absorbing water during wet periods and releasing it during dry periods. It also acts as a natural filter since percolation of water through the soil and other formations can remove certain impurities.

Inappropriate or unregulated development on or near aquifers can unfavorably affect this water resource in a number of important ways. By covering recharge areas with relatively impervious surfaces and effectively sealing them to percolation, development decreases recharge of the groundwater supply and increases funoff. Development that pumps water in excess of aquifer recharge rates will cause the groundwater reservoir to fall,, not only reducing the available supply but causing land surfaces to sink. Where fresh groundwater is located near saline groundwater, overpumping can also decrease the natural flow from fresh to saline, resulting in saline pollution of the freshwater reservoir. Again, land use activities can allow harmful substances to enter the aquifer, e.g. location of septic tanks or cesspools at or below the water table; subterranean disposal of wastes; agricultural activities involving concentrations of fertilizers or animal wastes; poorly constructed chemical or petroleum storage tanks; etc.

Wetlands. The term wetlands encompasses a variety of ecological areas that are generally classified by their vegetation, water type (fresh, saline), and predominant water depth. They include fresh or saline meadows, marshes, swamps, bogs, bays, and open water. These areas perform a number of vitally important natural functions. They affect water quality by filtering out silt and other pollutants, slowing down runoff, and changing inorganic nutrients into acceptable nutrient material. Wetlands also serve to stabilize water quantity by absorbing excess flows during flood periods and retaining it during droughts. Wetlands are particularly important for the maintenance of fish and wildlife habitat; they provide critical breeding, nesting, and feeding grounds for birds, fish and other aquatic animals, and contribute to the food chains of upland plants and animals. Finally, in addition to supporting general ecosystem health, wetlands also have important value as recreation, education, and aesthetic resources.

Development or alteration of wetlands can create serious water quality and related environmental problems. Upland development can lead to nutrient and sediment inflows that exceed the natural capacity of the wetlands to act as a "filter"; it can no longer efficiently transform nutrients into harmless inorganic matter and remove suspended sediment. The nutrients stimulate eutrophication and the increased turbidity resulting from the sediment reinforces this depletion of available oxygen in the stream, degrading water quality and creating fishkills. Wetlands may function as recharge areas for groundwater, groundwater discharge areas, or catch basins for overland flow. Development that increases upland runoff or affects groundwater levels can upset the intricate cycling of water between wetlands, groundwater, and surface water, impeding the wetlands ability to counteract floods and droughts.

Woodlands. Woodlands help protect soil resources by moderating the impact of storms and wind, thus reducing erosion and sedimentation. Also important for water quality, forest vegetation slows runoff, allowing pollutants to be filtered out before water reaches groundwater reservoirs. Clearly, woodlands represent valuable resources to the community for a host of other reasons. Aside from the economic value of the timber, they present opportunities for recreation activity and aesthetic enjoyment. They provide a diverse environment for a variety of plants and animals and thus constitute a significant resource for wildlife conservation. Woodlands also moderate the local climate, since the forest microclimate (shade, transpiration) stabilizes air temperature, and serve to buffer urban noise.

Unregulated development of woodland areas can lead to increased rates of runoff and erosion, resulting in increased problems of flooding and siltation. Increased pollutants reach groundwater reservoirs because of reduced natural capacity for removal. The forest ecosystem is particularly sensitive to chemical pollutants, such as the deicing salts used on highways. Destruction of woodlands may also remove attractive recreation sites.

Steep Slopes. Hillsides are geological features which, in combination with vegetation, soils, and precipitation, affect the natural balance of the hydrologic system. Hillsides move naturally as the result of gradual weathering and erosion. However, development that removes vegetation sharply increases soil and slope instability by increasing the amount of water in the soil. Construction that alters the natural formation of rocks, soils, and other components of a slope will make it more susceptible to slides and slumps. Development that removes vegetation or otherwise alters natural drainage patterns will increase runoff and erosion. Steep slopes and soils that are relatively less permeable (e.g., clays) are particularly sensitive to this problem. Radical changes in hillsides due to erosion will in turn have impact on surface water quality, groundwater quality and quantity, and stream flow. Use of improper construction techniques can leave the landscape permantly scarred. The aesthetic damage is compounded where site planning and design ignore the natural contours of the terrain and obliterate the hillside itself. Slopes have positive value to people as they provide distinctive relief to the landscape and interesting settings for human activities.

2.4.2 Needed Planning Coordination

Clearly, the various natural functions performed by these types of environmentally sensitive areas extend beyond merely maintaining or protecting water quality. Protecting sensitive lands for water quality purposes would appear to further a number of related community goals:

- protection of adequate groundwater supplies
- reduction of flood damage
- conservation of urban open space
- preservation of unique wildlife habitat
- enhancement of recreational opportunity

Restricting private development of such lands may also have negative consequences for other, equally valid, community goals such as

- adequate supply of local housing
- new business activity and jobs
- lower property tax rates
- higher property values

because of foregone economic development opportunities.

Thus, 208 planners interested in protecting sensitive areas from development for water quality purposes will be forced to consider the implications of their approach for a whole range of related planning considerations. 208 planners will have to coordinate their planning efforts with a number of other regional and local agencies, chief among these being the area responsible for master planning and economic development. Existing plans and zoning ordinances may call for more intensive uses than will be consistent with meeting water quality standards. Also, 208 planners will have to coordinate their efforts with other agencies developing functional plans for water supply, flood protection, coastal zone management, open space, and outdoor recreation. The objective will be to identify inconsistencies and reconcile conflicts that may exist among these various single-purpose separately conceived plans. An existing water and sewer plan may call for running a sewer through an area proposed, for water quality reasons, as a passive recreation area. Equally possible, existing transportation plans may not provide for automobile access to the same proposed recreation area. Regional solid waste planners at the same time may be considering location of a sanitary landfill within this same area.

2.4.3 Planning Support Activities

What these various connections between 208 and other community planning activities point to is the need to take into account the close relationship that exists between water quality concerns and land use decision-making.

There has been a growing recognition in the planning literature of the need to condition land use allocations on land suitability, that is, the capability of the land to accommodate the proposed use while maintaining the continued functioning of vital ecological processes.[10] This has been part of a larger movement toward grounding comprehensive planning in a firm base of natural resources data on an area's major environmental features.[11] Numerous methodologies now exist for identifying, interpreting, and mapping data on environmentally sensitive areas so that planners can make preliminary determinations of their suitability to a wide range of potential urban uses. These methodologies vary greatly in terms of data inputs, level of detail, extent of machine processing, etc., but they share a common planning objective. Each seeks to guide or otherwise restrict development on sensitive lands so as to assure continued performance of valued natural functions contributing to maintenance of environmental quality.

Some methodologies limit themselves to analysis of a single factor, such as soil conditions.[12] Other approaches, though still earth science-oriented, take into account a number of geologic conditions such as slope stability, flooding, erosion and sedimentation, bearing material problems, etc.[13] Still other planning approaches combine earth science with related natural resource and even visual-perceptual data in determining suitability of land for development. Some of these rely on map overlays and point rating systems for integrating multiple environmental variables,[14] others make use of computer graphics and related predictive models.[15] No systematic comparison has yet been done of the tradeoffs that exist among these various approaches in terms of the needed resources, i.e., time, money, technology, and specialised expertise. However, all of them do make maximum use of data available from published sources. The major data sources typically called upon are the U.S. Geological Survey, The Soil Conservation Source of the U.S. Department of Agriculture, the Army Corps of Engineers, State divisions of mines and geology, and regional water districts.

The environmental concerns of such land suitability studies are clearly wider than just protecting water quality, and they typically will not be generated as part of a 208 planning exercise. However, when these studies are available locally, they provide an invaluable resource to the 208 planner in identifying and mapping the water quality-related sensitive lands discussed above. Together with findings on the potential extent and magnitude of the non-point source pollution problem in the area, and projected future land use patterns given expected economic and population growth, they supply the needed planning base for implementing a program of sensitive areas protection and regulation.

REFERENCES

1. Linsley, Ray K., and Franzini, Joseph B., Water-Resources Engineering 2nd ed., McGraw-Hill, New York, 1964.

2. The following terms are commonly used to note various periods of time:

   a) "travel time" is the time for the flow to traverse from one point to another and can be estimated by dividing the average velocity by the distance traveled.

   b) "time of concentration" is the sum of the travel times from the farthest point in the watershed to the point of measurement. In terms of the hydrograph, it is the time from the end of excessive rainfall to the point of inflection on the falling limb of the hydrograph.

   c) "lag time" is the time from the center of the mass of excessive rainfall to the peak runoff. From a range of storms and watersheds it has been shown that the lag time is equal to six-tenths of the time of concentration, for average natural conditions and for approximately uniform distribution of runoff over the watershed. A limited number of studies indicates that this relationship holds for urbanized watersheds also.

3. In hydrologic terms the ratio is known as the "hydraulic radius" and is the ratio between the cross sectional area divided by the wetted perimeter.

4. Channel and storm sewer flow velocities can be estimated by the use of Manning's equation, in which velocity is a function of the cross-sectional area divided by the wetted perimeter, all raised to the two-thirds power:

$$V = f\left\{\frac{\text{cross-sectional area}}{\text{wetted perimeter}}\right\}^{2/3}$$

   See following footnote for Manning equation.

5. The complete Manning equation is: $V=\frac{1.49}{n} \cdot R^{2/3} \cdot S^{1/2}$, where V is the velocity of flow, R is the hydraulic radius, S is the slope, and n is the coefficient based on the roughness of the surface over which the flow occurs.

6. Linsley, Ray K., and Franzini, Joseph B., Water-Resources Engineering, 2nd ed., McGraw-Hill, New York, 1964.

7. Bhutani, Joginder; Holberger, Richard; Spewak, Peter; Jacobsen, William, and Truett, J. Brian, Impact of Hydrologic Modifications on Water Quality, U.S. Environmental Protection Agency, Report EPA-600/2-75-007, April 1975.

8. Gray, Donald H., "Soil and the City," *Urbanization and Environment*, Detwyler, Thomas R., and Marcus, Melvin, ed., Duxbury Press, Belmont California, 1972.

9. The discussion of these five types of sensitive lands draws heavily on *Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators*, U.S. Environmental Protection Agency, March, 1975, EPA-600/5-75-005. Not all environmentally sensitive areas are covered (e.g. floodplains, major river basins, large lakes) but only those where *local* governments can "make an immediate, recognizable impact" (p. 18).

10. For the best recent discussion of trends in environmental planning, see *Promoting Environmental Quality Through Urban Planning and Controls*, U.S. Environmental Protection Agency, February, 1974, EPA-600/5-73-015. Regarding land suitability approaches, see especially pp. 119-133.

11. See Carl Steinitz et al., *A Comparative Study of Resource Analysis Methods*, Harvard Graduate School of Design, 1975; also Raymond Belknap and John Furtado, *Three Approaches to Environmental Resource Analysis*, The Conservation Foundation, 1967.

12. Generally the soil mapping work of the Soil Conservation Service, U.S. Department of Agriculture. Also see *Soils Development Guide*, Southeastern Wisconsin Regional Planning Commission, 1969.

13. See for instance U.S. Geological Survey - Association of Bay Area Governments, *Land Capability Analysis*, 1975 (part of the San Francisco Bay Region Study jointly funded by U.S.G.S. and the U.S. Department of Housing and Urban Development).

14. Two excellent recent examples are the *Dallas Ecological Study*, City of Dallas Department of Planning and Urban Development, 1973; and *Performance Requirements for the Maintenance of Social Values Represented by the Natural Environment of Medford Township, New Jersey*, Department of Landscape Architecture and Regional Planning, University of Pennsylvania, 1973.

15. See Timothy Murray et al., *Honey Hill: A Systems Analysis for Planning the Multiple Use of Controlled Water Areas*, U.S. Army Engineers Institute for Water Resources, prepared by the Department of Landscape Architecture Research Office, Graduate School of Design, Harvard University, 1971. Especially valuable as a survey of extant computer-based land use planning models is Appendix D.

3.0 TECHNICAL APPROACHES

This chapter discusses a number of technical approaches which may be employed to reduce water pollution due to urban stormwater runoff. Since all of these approaches are applied before the runoff reaches the storm sewer system, they may be termed "preventive approaches." These individual techniques form the basis for a system of Best Management Practices. The concept of Best Management Practices seeks to control the twin results of urbanization: increased runoff and increased pollution. The technical approaches described here are grouped into three categories, according to the specific runoff problem addressed:

- Measures to reduce runoff pollution due to surface and subsurface pollutants;
- Measures to reduce runoff and increase infiltration; and
- Erosion and sedimentation control measures.

In order to place the purpose of these management practices into perspective, it is useful to reiterate some notions about the nature of the problem and its constituents. Table 3-1 compares total quantities of raw municipal waste and urban runoff, including base flow, in pounds per acre of drainage basin size per year. These figures are taken from a study done at Durham, North Carolina and are meant only to serve as an example of the problem. Urban runoff contains much greater loads of suspended solids and heavy metals than raw municipal waste.

Table 3-2 gives the total annual yield of pollutants from municipal and urban runoff sources in pounds per acre during 1972 based on actual removal rates for the Durham Third Fork Sewage Treatment Plant. On a yearly basis, the average ultimate BOD reduction is 46 percent, COD--48 percent, and suspended solids--4 percent.

It is important to note here that even if Durham provided 100% removal of organic and suspended solids from raw municipal waste on an annual basis, the total reduction of pollutants discharged would only be 52% of the COD, 59% of the ultimate BOD, and 5% of the total suspended solids.[1] Although urban runoff varies widely in its severity, it can be a significant source of water pollution in some areas and, where this is true, some means must be devised to control it, over and above the control of municipal point sources. The means of control presented here are Best Management Practices.

Table 3-1

COMPARISON OF RAW MUNICIPAL WASTE AND URBAN RUNOFF ON AN ANNUAL BASIS IN POUNDS PER ACRE PER YEAR POLLUTANT YIELD

Pollutant	Raw Municipal Waste lbs/ac	%*	Urban Runoff + Base Flow lbs/ac	%*	Total Annual Yield (lbs/acre)
COD	1,027	52%	938	48%	1,965
BOD Ultimate	685	59	470	41	1,155
Suspended Solids	335	5	6,690	95	7,025
Kjeldahl Nitrogen as "N"			6.1		
Nitrate "N"	7.2				
Total Phosphorus as "P"	11	73	4.7	27	15.7
Chromium	.10	6	1.6	94	1.7
Copper	.20	11	1.6	89	1.8
Lead	<.8	21	2.9	79	3.7
Nickel	<.16	12	1.2	88	1.3
Zinc	1.5	43	2.0	57	3.5

*% of total annual yield

Table 3-2

TOTAL ANNUAL YIELD OF POLLUTANTS FROM MUNICIPAL AND URBAN RUNOFF WASTES IN POUNDS/ACRE DURING 1972

Parameter	Municipal Waste (lbs/ac) Raw	Percent Removal	(lbs/ac) Effluent	(lbs/ac) Urban Runoff	(lbs/ac) Total Release	Overall Removal Efficiency
COD	1,027	91*	92	938	1,030	48%
Ultimate BOD	685	91	61	470	531	46%
Suspended Solids	335	85	50	6,690	6,740	4%

*Assumed

The object of Best Management Practices is to prevent and reduce urban runoff pollution. As such, it is a system of source control. The first group of Best Management Practices are those measures intended to reduce runoff pollution due to surface and subsurface pollutants, attempting to hold and check that material which reaches the impervious surfaces of the urban environment. Such controls are typically chemical application restrictions, litter control, and other public works activities such as street sweeping and catch basin cleaning. The second group, measures to reduce runoff and increase infiltration, seeks to correct the problem engendered by urbanization through such techniques as porous pavement and dutch drains. The third set, erosion and sedimentation control measures, have been largely developed through the work of the Soil Conservation Services.

These preventive approaches generally can be applied at one of two points in the development process. A number of the solutions refer to construction practices, which should be applied by the developer when earth disturbing activities occur. Some erosion and sedimentation control measures, as well as measures to reduce runoff and increase infiltration, may be considered as requirements of development after construction is completed. Implementation of these two types of measures (construction practices, post-construction requirements) is typically the responsibility of the developer, while municipalities will generally be responsible for off-site controls on surface and subsurface pollutants. Of course, in the case of construction of public facilities, the municipality or other public agency itself may act as the developer and thus face the same obligations as the private developer.

It should be realized that the urban environment is merely the collector of what we put into it; the impervious surfaces provide the means of transport for this material and rainfall acts to flush those surfaces. Again, the concept of Best Management Practices seeks to prevent and reduce this pollution from reaching the receiving water. In so doing, the goal is to protect the beneficial uses intended for those waters. No one technique alone described here can correct the changes brought about by urbanization. Combinations of these management practices which are designed to control recognized sources are required. If such is done, a system of Best Management Practices can be brought about to control urban runoff pollution effectively and yet relatively inexpensively.

Implementation of all these technical approaches can generally be achieved through use of some combination of zoning ordinances, subdivision regulations, building codes, health codes, erosion and sediment control ordinances, and other specialized regulations. Public officials, however, should look to voluntary compliance through public awareness programs before seeking to enforce stormwater runoff programs through regulatory instruments. Regulatory aspects of urban stormwater management are discussed in greater detail in Chapter 4. The costs of installing and maintaining the construction and post-construction control measures are borne by the developer and passed on to the eventual occupants of the development. Surface and subsurface pollutants controls are typically paid for out of public funds. Financing needs, methods, and sources for a number of control measures are discussed separately in Chapter 5.

3.1 Measures to Reduce Runoff Pollution Due to Surface and Subsurface Pollutants

Pollution of stormwater runoff occurs largely from *four* major sources:

- dust fall
- contact with municipal and industrial wastes in combined sewers;
- litter, debris, and chemicals (including pesticides and fertilizers washed off vegetation) on parking lots, streets and alleys; and
- silt resulting from soil erosion.[2]

A number of measures designed to reduce runoff pollution due to surface and subsurface pollutants are discussed in this section. Five subsections are presented, dealing with the following problems: street litter, highway deicing, fertilizers and pesticides, land disposal of wastes, and infiltration/inflow.

The first subsection discusses the problem of runoff pollution due to street litter, considering such measures as street cleaning and catch basin cleaning. The second subsection considers the application and storage of deicing salts, and presents alternatives to the use of salt on highways. The application and storage of fertilizers and pesticides are examined in the third subsection, also considering the possibility of licensing persons handling and applying such chemicals. The fourth subsection discusses the design, location, and operation of septic tank systems and sanitary landfills. The final subsection considers the problem of infiltration/inflow into sewer systems and examines such remedies as the inspection and removal of illegal drain connections.

The measures presented in this section vary in a number of important ways from those to be presented later. In most cases these measures involve operational solutions (nonstructural solutions) not involving the construction of a facility. The measures presented in this section are generally applied after development has been completed, and are designed to reduce the impact of various pollutants remaining after structural methods have been installed.

Implementation of these measures is often the responsibility of the locality rather than the developer since, in many cases, the pollutants have been deposited on public streets after having been carried off from the development. They also involve control of off-site pollutants, that is, pollutants generated elsewhere. Several other measures are clearly the responsibility of the locality, because they deal with residuals from public activities such as highway deicing, fertilizer and pesticide use on public lands, and operation of sanitary landfills. The infiltration/inflow problem occurs at the interface between development and the public sewer system, while the design and operation of septic tank systems is usually the responsibility of the developer.

3.1.1 Street Litter

This subsection addresses the problem of urban stormwater contamination by street litter. A variety of materials may reach the street surface, including: animal wastes, garbage, grit, oil, road salt, cinders, residual particulates resulting from auto tire and brake use, and other materials. The measures presented in this subsection are designed to remove these materials before they reach the sewer system or other receiving waters (lake, creek, stream, etc.). Two major solution approaches are presented: street cleaning and catch basin cleaning. A number of other nonstructural measures will also be discussed which may reduce the effort required for these two approaches.

Although the accumulation of a certain amount of street surface contaminants is inevitable, much of the litter that reaches the street surface may be eliminated, or at least effectively controlled, at its source. A direct approach to reducing the runoff pollution potential can best be accomplished through active public education and through effective and enforceable regulations and ordinances relating to street cleanliness. The local government can do its part by providing an adequate number of litter containers, which should be kept presentable and emptied frequently. Strict cleanliness practices should be followed by city waste collection forces and other city departments which generate litter. Well-publicized cleanup campaigns can also provide motivation for the public to clean up the premises and dispose of accumulated trash.

Ordinances may be established describing improper littering practices and prescribing penalties for violation. In addition to general anti-litter ordinances, specific regulations may be directed to the following typical sources of litter in the urban environment: garbage and refuse collection, open trucks, public litter receptacles, refuse dumping, building construction and demolition, street construction, sidewalk sweeping, vacant lots, parking lots and garages, drive-in restaurants, trailer courts and campgrounds, sports stadiums, auditoriums and exhibition halls, theatres, food handling establishments, pet control, distribution of handbills, posting of notices and political posters, street vending, garden refuse, scavengers, weed control, dead animals, produce markets, and direct discharges into storm sewers.

The effectiveness of local ordinances will depend on enforcement, which will depend in turn on effective interdepartmental cooperation. For example, the police department can enforce ordinances pertaining to littering from moving vehicles, illegal dumping of refuse, the storage of construction materials on sidewalks and streets, etc. The fire department can enforce regulations pertaining to storage of refuse which might create a fire hazard. The health department can regulate the handling and storage of refuse by food-handling establishments. Enforcement by these agencies should include both inspections and summonses.[3]

Street Cleaning: Improved street cleaning practices, including increased frequency of street cleaning and increased removal efficiency of street cleaning methods, may serve to reduce runoff pollutant loadings and to reduce first flush effects in sewers. Motorized street sweepers are designed to loosen dirt and debris from street surfaces, transport it onto a moving conveyor, and deposit it temporarily in a storage hopper. The major types of street sweepers include the broom-type sweeper, the vacuum-type sweeper, and a third type of sweeper which uses a regenerative air system to "blast" dirt and debris from the road surface into a hopper.[4]

Mechanical street sweeping is ineffective for fine solids, which account for only 5.9% of total solids, but 25% of oxygen demand. The following removal efficiencies have been estimated: total solids, 25%; BOD, 45%; COD, 30%; nitrates, 45%; phosphates, 20%; heavy metals, 50%; and total pesticides, 45%. Sweeping efficiency, however, varies with the area, rainfall, frequency of passes, frequency of cleaning, and the skill of the operator.[5]

The accumulation of street surface contaminants may be minimized by increasing the frequency of street sweeping operations. Commercial areas are generally swept more often than other land use areas. The effectiveness may also be improved by sweeping an area more than once. Repeated passes over the same area can effectively reduce the amount of pollutants remaining. Since there are only a finite number of available vehicles, however, an increased utilization of street sweeping may require additional resources to be outlayed by the responsible agency.[6]

Street sweeper costs vary widely, depending upon the individual model. The following capital costs are representative of that range: 3-wheel, $21,000-25,000; 4-wheel, $32,000-35,000; and vacuum, $35,000-40,000.

A rough estimate of capital costs required for a given street sweeping program would be on the order of $10 to $15/curb mile cleaned per year, for the sweepers alone (ENR 2000). Operation and maintenance costs will vary more widely due to local conditions such as labor markets and the condition of the streets swept. Vacuum sweepers, in particular, may have multiple uses. Porous paving, for example, requires sweeping by vacuum to prevent clogging of the pores which allow water to seep through. Moreover, a wandering hose attachment to the vacuum permits cleaning of catch basins to a certain degree.[7]

A major problem in most of the larger cities is parked or abandoned cars. Parked cars make it impossible for street cleaning equipment to clean all of the street. Part of this problem may be solved by parking regulations which prohibit parking during specific hours. Some cities overcome this problem by sweeping during rush hours when parking regulations and tow-away zones are enforced. In residential areas, these parking restrictions may apply only once or twice a week, while in commercial areas they may apply every day. The problem of abandoned cars is much more difficult to control, particularly in very large cities. Abandoned cars not only interfere with street cleaning operations, but are a source of litter. Abandoned cars should be removed from the streets as soon as possible, either by city forces or by a private contractor hired by the city. The sale or auction of operative vehicles (and possibly the sale of parts) from a city-owned and operated junk yard could help defray the cost of removal.[8]

Street cleaning will only be effective when no-parking regulations can be enforced. When this is not feasible, other approaches must be considered, such as catch basin cleaning.

Catch Basin Cleaning: Catch basins became standard before paved streets came into common use and were installed partly to prevent sewers becoming clogged with gravel, partly as an odor seal. When regularly cleaned, catch basins are found to be effective in removing fine solids. However, few are cleaned regularly enough (in many cities, once yearly at most; in some cities, once every four years) and may become a serious source of organic sludge.[9]

Catch basins can be cleaned regularly in areas which are not serviced by street sweeping equipment, depending on the remaining capacity of the catch basins. The cost of various methods of catch basin cleaning are on the order of $3 to $4 per catch basin.[10] Catch basins remove approximately 56% of total solids and about 40% of BOD.

3.1.2 Highway Deicing

Deicing salts and their additives may cause serious water pollution problems and deteriaration of roadside vegetation. If salt is used to deice highways, the problem can be reduced through careful application and storage, but not entirely eliminated. Deicing salts are used in nearly every state in the snow belt. Heavier applications are often used on steep slopes; therefore, the problem may be worse in hilly areas. Aquifer recharge areas are particularly susceptible to groundwater pollution from deicing salts, due to the rapid movement of chloride ions in the soil. These measures generally apply to public agencies, except where private developments include large paved areas.

The use of deicing salts results from the demand for bare pavements during periods of snow. This policy is based on safety considerations. For example, stopping distances are 478' on icy pavement, 183' on sanded pavement, and 66' on salted pavement (bare, but wet). However, use of deicing salt also causes serious corrosion to automobiles and highway structures, may damage the pavement (especially uncured concrete), and may cause deterioration of roadside soils. Additives to deicing salts may also be pollution hazards (e.g., cyanide from the breakdown of an anticaking agent).[12]

Measures to be considered include: greater use of sand in place of salt in less critical icing areas; greater use of mechanical snow removal techniques; careful metering of salt where used; careful storage of salt; and the minimization of damage to vegetation due to runoff of deicing salt by the use of salt tolerant species for plantings.

At present there are no economical alternatives for sodium chloride and calcium chloride mixes for deicing highways. The use of abrasives alone is not sufficiently effective for public acceptance, and costly programs would be required to empty sediment traps, clean curbs, etc. Salt use, however, may be reduced without sacrificing safety: no salt application on straight, flat sections; better training of operators on salt-spreading equipment; and improved records of salt use.[13] In addition, new types of salt spreaders and snowplows may be considered, as well as improved cab monitoring devices that will control salt application more accurately.

A number of other possibilities were examined in an EPA-sponsored study: external in-slab thermal melting, stationary/mobile melters, substitute deicing compounds, compressed air types of snowplows, adhesionreducing pavement materials, solar energy-storing pavement substances, electromagnetic ice shatterers, improved drainage (enhancing runoff, accident reduction, and snow melt control/treatment), salt retrieval/treatment, and improved tire/vehicle design.[14]

An alternative to salt is the use of abrasives such as sand and cinders. However, abrasives do not fit into the "bare pavement" policy which now prevails, and they can become stormwater pollutants. Although abrasives generally contribute only small amounts of dissolved solids to runoff, they can contribute significant portions of the suspended solids. Large quantities of sand and cinders can clog storm and combined sewers. Most cities remove a large portion of the abrasives during street cleaning, but the added cost of collecting large amounts of sand and cinders must be included in the cost of their use. In addition, abrasives are more expensive (by weight) than sodium chloride. With salts, however, many of the costs (such as those for corrosion damage, degradation of water supplies, and damage to roadside vegetation) are indirect and often ignored. Hence, in some instances, a more complete economic comparison might favor abrasives over salt.[15]

Salt storage sites should be chosen not only for their accessibility, but also because they are well drained, not on an aquifer recharge area, and not subject to overland runoff from upslope areas. Storage areas should be covered for protection. During loading, the area of the storage heap uncovered at any one time should be minimized and, following loading, the loading pad should be thoroughly swept. Cleaning of spreading equipment should be carried out on the loading pad where brine will discharge into a holding vault. Better designed salt-handling equipment for loading spreaders to eliminate scatter and waste should be developed.

Roadside planting may be affected by the salt concentration in the soil or by spray: salt-tolerant species of trees and grass should be used for all new plantings. Tree plantings should avoid areas where salts tend to accumulate (hollows, etc.). Existing sensitive species should be protected by diverting contaminated runoff away from their root systems. These recommendations apply principally to plantings within 30' of the pavement.

A major consideration for highway maintenance is the fact that use of abrasives in deicing mixtures mixtures will necessitate clean-up operations following thaw, especially sediment traps (about $3 each). Also, buildup of salt concentrations in highway soils will be reduced if mowings are harvested (suggested for recharge areas), and "dead ponds" will require annual clean-out if they are found to be feasible.[16]

Some courts have stated clearly that once an authority has started to maintain a road in a certain condition, it must continue to do so or run the risk of liability suits. The Minnesota legislature has approved restrictions on the use of deicing chemicals in order to: (a) minimize the harmful or corrosive effects of salt or other chemicals upon vehicles, roadways, and vegetation; (b) reduce the pollution of waters; and (c) reduce the driving hazards resulting from chemicals on windshields. Road authorities, including cities, villages, and boroughs, responsible for the maintenance of the highways, are limited to using deicing salts or other chemicals only upon hills, and only if, in the opinion of the road authorities, removal of snow by plowing or sanding or by natural elements cannot be accomplished within a reasonable time.[17]

3.1.3 Fertilizers and Pesticides

A number of measures may be employed to prevent pollution of runoff due to chemical use on municipal land (parks, recreation areas, golf courses, urban open spaces, etc.) as well as on agricultural land in urbanizing areas. The indiscriminate use of chemicals for the control of unwanted pest infestations and the improvement of soil and plant nutrient conditions should be reduced. The limited use of these chemicals should be consistent with their intended purpose, and careful attention should be paid to their storage and distribution.

A professional licensing system for handlers and users of pesticides and fertilizers may be practical. Such licenses would be awarded only to those who demonstrated competence in the handling of such materials, and could be revoked for failure to comply with applicable regulations designed to prevent the introduction of such materials into ground or surface waters. Alternatives to the use of fertilizers and pesticides should also be examined.

3.1.4 Land Disposal of Wastes

This subsection discusses the design, location, and operation of septic tank systems and sanitary landfills to minimize the problem of polluted runoff due to land disposal of wastes. These facilities should be designed to take into account population density, type of development, and the natural characteristics of the site. Surface runoff can introduce septic tank seepage into receiving waters when a combination of high usage and heavy rainfall are present. Overconcentration of septic tanks within a given area can overtax the assimilative ability of the subsoil strata. Septic tanks serve their purpose best when population densities are low.

The soil condition surrounding a septic tank plays a vital role in its operation. If this strata contains clay-related soils, then a semi-permeable condition exists which will allow very little, if any, absorption. Capillary action may then cause seepage to rise to the surface, where it can be picked up by surface water runoff. Clay-related soils also contribute to lateral movement, rather than downward movement, of septic tank seepage. This seepage will tend to seek its own level and will move along the path of least resistance until other soil types affect it. At this point it can be either further absorbed or move closer to the surface.[18]

Septic tank systems should be used only in low density developments and only where soils are well-drained. Periodic maintenance is required to provide reliable operation. Septic tanks should be pumped out at approximately 2-year intervals to remove solids that have built up. It is important not to overload the system to ensure a long life span for the field disposal system. Water from roof drains or foundation drains should not enter the system.[19]

Many states have adopted detailed regulations to govern the operation of sanitary landfills, in order to prevent pollution of ground or surface water from leachate or overflow at the disposal site. Regulations of the State of Hawaii prohibit the establishment or operation of any solid waste disposal facility without a permit from the State Director of Health. Permit applications must be accompanied by detailed plans and specifications for the facility and by an operations plan report. Permittees are required by these regulations to compact and cover all solid waste accumulated after each day's operation with earth or other approved material so as to safeguard the environmental quality of the surrounding area. They are also required to have monitoring equipment in place to detect any pollution or contamination that might result from operation of the facility; to maintain a minimum vertical separation of five feet between the deposited waste and the anticipated high groundwater table; to have adequate provisions for minimizing the flow of off-site drainage over the landfill; and to deposit solid wastes in such a manner as "to prevent waste materials, leachate, or eroded soil particles from entering the waters of the State without receiving the best practicable treatment or control."[30]

Regulations of this type might also establish limits on the widths of the working space, require all lifts to be graded so as to facilitate drainage, and require the operator to meet periodic self-monitoring, recording, and reporting requirements. Lagooning of sewage, sludge, or seepage could be prohibited, as well as acceptance of infectious or otherwise hazardous wastes. Sanitary codes may specify the requirements for design, location, and operation of septic tank systems.

3.1.5 Infiltration/Inflow

Serious problems result from excessive infiltration into sewers from groundwater sources, as well as from high inflow rates from sources other than those which the sewers were intended to serve. Infiltration is the volume of groundwater entering sewers and building sewer connections from the soil through defective joints, broken, cracked or eroded pipe, improper connections, and manhole walls. Inflow is that volume of water discharged into sewer lines from such sources as roof leaders, cellar and yard drains, foundation drains, commercial and industrial "clean water" discharges, drains from springs and swampy areas, depressed manhole covers and cross connections.

Inflow sources generally represent a deliberate connection of a drain line to a severage system. These connections may be authorized and permitted, or they may be illicit connections made for the convenience of property owners without consideration of their effects on public sewer systems. The intrusion of these waters takes up flow capacity in the sewers, and, especially in the relatively small capacity sanitary sewers, they may cause flooding of street and road areas, thus constituting a health hazard. In this case the sanitary sewers actually function as combined sewers, and the resulting flooding becomes a form of combined sewer overflow.[21]

The measures presented in this subsection concentrate on the reduction of inflow to the sewer system. Correction of inflow conditions is dependent on regulatory action on the part of city officials, rather than public construction practices. If elimination of existing inflows is deemed necessary because of adverse effects of these flows on sewer systems, pumping stations, treatment plants, or combined sewer regulator-overflow installations, new or more restrictive sewer-use regulations may have to be invoked.

The effects of inflows into sewers can be greatly reduced by a number of methods. Many authorities advocate the discharge of roof water into street gutter areas or onto on-lot areas in the hope that it will percolate into the soil. Discharging roof or areaway drainage onto the land or into street gutters reduces the immediate impact on the sewer system by allowing reduction of the volume and attenuation of the flow. The use of pervious drainage swales and surface storage basins within urban areas allows the stormwater to percolate into the ground (see Section 3.2.3).[22]

The removal of connections of roof drains to sanitary or combined sewers is a method commonly used to reduce the hydraulic loading on sewers and sewage treatment plants. A successful program of removal of roof drain connections can provide an effective and economical means of reducing local flooding and pollution problems if satisfactory means are employed on-site to handling resulting roof drainage.[23] Direct connection of roof drains to sewers allows large volumes of rainwater to reach the sewer system in a short period of time. If roof downspouts were permitted to discharge on ground surfaces instead of into sewers, there would be opportunity for infiltration, detention in small puddles, and subsequent evaporation of the stormwater, and that portion of the drainage which reached sewer inlets would be reduced. These various measures can reduce sewer flows appreciably.[24]

Inspection and removal of illegal drain connections costs approximately $3 per building inspected and about $4 per downspout removed. Considerable savings at the sewage treatment plant may be realized due to reduced inflow.[25] The removal of downspouts from a sanitary sewer system will provide favorable results in the form of reduced complaints, reduced operational costs, and improved operation of the treatment works. While similar results may not be as apparent on a combined system, nevertheless such a campaign can be most effective.[26] Sanitary ordinances may prohibit the connection of roof drains to sanitary sewers, but, if they are not enforced, the inflow problem may remain.

Excessive infiltration is a serious problem in the design, construction, operation, and maintenance of sewer systems. Neither combined sewers nor separate sanitary sewers are designed to accept large quantities of such infiltration flows. The problem of infiltration involves two basic areas of concern: (1) prevention in new sewers by adequate design, construction, inspection, and testing practices; and (2) the elimination or cure of existing infiltration in old sewers by proper survey, investigation, and corrective measures. Control of infiltration in new sewer systems involves engineering decisions and specifications of the methods and materials of sewer construction, pipe, joints, and laying procedures and techniques. Correction of existing sewer infiltration can be accomplished by three basic approaches: replacing the defective component, sealing the existing openings, and building within the existing component.[27]

3.3 Measures to Reduce Runoff and Increase Infiltration

The urbanization process involves an increase in the total area covered by impermeable surfaces, leading to two related problems: increased runoff and decreased infiltration. The technical approaches presented in this section are divided into two subsections: delay of runoff on-site and increased infiltration on-site. The major objective of these measures is the maintenance of runoff volumes and peaks from areas undergoing urban development at or near those from areas under "natural" (rough grassland) conditions. Additionally, measures to increase infiltration may also serve to maintain sufficient infiltration to shallow ground water to ensure no retardation in the dry weather flow of streams and to maintain recharge of major aquifers at a level equivalent to those under natural conditions.

Reduction of runoff volumes and peaks will lead to reduced frequency of flooding and lower flood peaks, along with reduced risk of erosion and sedimentation. Increasing infiltration to maintain dry weather flow in streams will reduce the impact of various pollutants on the stream quality, since sufficient dilution flow would be available. Finally, maintenance of aquifer recharge will ensure an adequate water supply.

The technical approaches to be presented are generally permanent measures which must be installed by the developer and must remain in place after the development is completed. A number of the measures, however, may be applied as modifications to existing developments, in order to reduce water pollution problems.

3.2.1 Delay of Runoff On-Site

Delay of runoff, or on-site detention, may be accomplished by a number of approaches:

- storage in permanent ponds having provision for variable depth,
- temporary ponding on paved areas, and
- temporary ponding on roofs of buildings

On-site detention of stormwater runoff can be an effective, economical method or urban stormwater management. Besides controlling local flooding and water pollution, on-site detention may also provide aesthetic benefits, recreational opportunities, reduced erosion and sedimentation hazard, and augmentation of local water supplies (in some cases). On-site detention of runoff appears most desirable in flood-prone or erosion-prone areas, and the economics seem favorable for both new developments and existing urbanized areas. On-site detention will prevent overflow of combined sewers, may permit smaller storm sewers to be used, and may reduce flow rates in sewers to levels at which treatment would be feasible.[28] However, a number of problems must be considered before implementation of such measures is practical.

The legal basis to require property owners and land developers to provide and operate stormwater detention facilities must be examined. Some of the types of legislation used by local jurisdictions to control stormwater runoff from new land developments and urban renewal projects include: subdivision regulations, zoning ordinances, building codes, plumbing and sewer ordinances, water pollution control ordinances, flood control ordinances, and drainage fee assessment ordinances (some of which provide for reducing the assessment if stormwater detention facilities are installed). Water pollution laws in Maryland recognize silt as a water pollutant, and detention ponding is used to control sedimentation from erosion of land developments, particularly during the construction period. State flood control laws, such as in Virginia, have been interpreted broadly to allow for the inclusion of the requirement for detention ponds to control flooding. Most local building codes do not require detention storage, although some public agencies (e.g., the Denver Urban Renewal Agency) do require that rooftop storage be incorporated into the design of buildings.[29] Jurisdictions that mention rooftop storage in building codes specify various standards of construction, including the maximum water depth on roof, roof slope, size of roof drainage leaders, and the number of leaders for a given roof area. At least one national organization, the Building Officials and Code Administrators, International, has developed standards for detention storage of rainfall on roofs.

Additional legal considerations or complications may include the following: legal responsibility for maintenance of detention storage facilities, whether rooftop, parking lot, surface pond, or other facility; legal responsibility for damages resulting from operation or physical failure of stormwater detention facilities; legal responsibility for damages caused by excessive flows of stormwater when released from facilities located on public or private lands; legal responsibility for providing safety facilities to minimize the hazards of on-site detention facilities, especially as an attraction to children; and the legal right to use or consumption of the stored stormwater, thereby disturbing normal flows of water into areas downstream from detention facilities.[30]

Potential political problems include that of modifying existing laws, building codes, zoning ordinances, subdivision regulations, etc., to include requirements for on-site detention of stormwater runoff that are practical and effective for solving water pollution and drainage problems, and are also acceptable to politicians and officials of the various public agencies involved. Related administrative problems may involve enforcement of the laws and regulations as established.[31] Enforcement of local laws pertaining to land development usually includes inspection, approval of construction, and provision for fines or other penalties. For example, under the subdivision regulations of a community, the initial plat may not be approved unless stormwater detention facilities are provided for in the plans submitted. Under the community's sewer permit ordinances, connections to the sewers might not be permitted until adequate detention of runoff is provided. If either law is violated, penalties can usually be assessed. This, of course, is an effective means of obtaining compliance.[32]

Another factor which must be considered is the problem of securing public acceptance of on-site detention as the best, or most practical, method of handling runoff in their community. A public education program might be beneficial to explain the alternatives and the reasons for choosing on-site detention.[33] Related acceptance problems may also be associated with the design and construction of storage facilities, including: the accurate determination of runoff rates (existing and future), the availability of space for construction of facilities, the capacity of downstream facilities to handle outflows, the need to build facilities to be aesthetically pleasing and compatible with the local environment, and the reluctance of builders, architects, and building owners to store water puposefully on roofs of buildings.[34]

Financial problems may arise concerning allocation of the costs of the facility and obtaining financial aid for defraying both the initial and on-going costs. Land developers are often required to bear the entire cost of construction of detention facilities in the same fashion that they must pay for sewer construction. In existing land developments, the costs are not usually borne directly by the property owners in the area served by the facility.[35]

The biggest problem of implementing effective stormwater detention programs is in obtaining cooperation from neighboring local jurisdictions. Since major floods in a community are often the result of excess runoff flows from nearby upstream communities, flood-prone areas must depend upon upstream communities to implement programs of flood control which may provide little direct benefit to these neighboring communities.[36] A number of the above problems may apply in the implementation of erosion and sedimentation control measures, as discussed in the next section.

Use of detention storage may reduce the size of the storm sewers required. Regular maintenance must be provided on rooftops to clear any clogging materials. In totally developed areas, rooftop storage may be the only feasible solution; land for open-space detention ponds and basins may not be available and the use of deep tunnels or underground tanks may be impractical, either because of initial cost, cost of operation, geological conditions, or the rules and regulations of the public agencies involved.[37] It seems that the economics of on-site stormwater detention may be quite appealing. If the detention facility can serve multiple-purpose uses, such as recreation, the economic potentials become even more attractive because a portion of the cost of the facility is allocated to other uses.

Surface Basins and Ponds. Usually detention basins and ponds constructed on ground surfaces are relatively large, having the appearance of a small pond or lake. The design of such facilities will vary depending upon the land costs, space availability, physical and aesthetic characteristics of the area, topography, climate, and other local factors. Whether or not the detention facility is to serve multipurpose uses, such as recreation, is a factor that may also dictate size, shape, depth, and landscaping treatment. For example, a detention pond designed to serve as a recreational pond for boating and fishing would require different design criteria than a pond which is to serve the single function of stormwater detention. Generally speaking, the availability of large open areas will permit a design having gentle side slopes and extensive landscaping, while sites where land is limited might dictate deep ponding areas, pumped discharge, and steep side slopes that require fencing and other security measures to minimize safety hazards to children.

The major design characteristics are the volume of storage needed and the maximum permitted release rate. Storage volume needed is given by the maximum difference, at any time, between cumulative total inflow volume and cumulative outflow volume measured from the beginning of inflow. The maximum permitted release rate can be calculated by determining the maximum discharge capacities of downstream sewer systems or receiving streams, and taking into account administrative restrictions that may be imposed by local authorities to regulate the discharge rate.[38]

A detention basin is the most effective technique for reducing the peak flow at a point immediately downstream of the impoundment, and should be used where frequent flooding of the area immediately downstream is intolerable. Detention ponds can be used to delay runoff on sites where seepage at the source is infeasible. A detention pond requires some sort of collection system to feed it. Developers may find that the cost of the collection system makes the provision of "at source" detention more economical. However, where "at source" methods are expensive or infeasible, detention ponds may be used. They are especially suited to cluster development where ponds can be incorporated into open-space systems.

A detention pond can be designed to catch a large proportion of suspended solids of more than 10 microns in diameter. A pond with a large freeboard for detention may have some recreational and aesthetic benefits if the runoff is not carrying too much sediment. However, a detention pond for maximum runoff control will have very little recreational or aesthetic value. Detention ponds that empty out entirely can have an unsightly nature that can be a detriment in urban developments. Detention ponds hold runoff and release it at a slower rate, which normally results in a flattening of the hydrograph. As a result, detention basins and ponds may allow a significant reduction in the size of required storm sewers.

An example of a jurisdiction which has incorporated detention devices into its regulatory framework is New Castle County, Delaware. Section 440 of the New Castle County Ground-Water Drainage Code states that "in order to minimize downstream flow increases, developers may be required to provide on-site stormwater storage capacity in the form of delayed runoff designs. Such improvements shall be required when downstream improvements are physically or economically impractical, or when increased runoff is disproportionate to the rest of the area.[39]

Young et al. report the following estimated capital costs for detention tanks of various sizes, along with the removal efficiencies of biochemical oxygen demand (BOD) and suspended solids.[40]

Cost and Performance
of Detention Tanks

Detention Tank Volume Gallons/acre	Capital Cost $/acre	BOD % Removal	Suspended Solids % Removal
2500	$ 1400	18%	37%
7500	4300	32	58
15000	8600	38	65
25000	14400	39	67

Source: Young, G.K., et al. Model to Design Stormwater Detention Tanks for Nonpoint Source Pollution Abatement. April 1975. (Unpublished)

Parking Lot Storage. Temporary storage of stormwater on parking lots is another means employed to reduce runoff rates and sewer loadings. The use of paved plazas in and around commercial buildings and office buildings to detain stormwater is similar to the use of parking lots. However, there are differences betwen these two approaches with regard to tributary drainage areas, grading requirements, and the maximum depth of water that can be ponded before causing inconvenience to the public.

Unlike ponding on rooftops there is no limit, from a structural standpoint, to the depth of water that can be stored. Another advantage is that the surface does not need to be dead-level as is true in the case of rooftop storage. Because of the ease of inspection and access, the maintenance and operation of parking lot storage facilities is a low cost item and easy to perform with mechanical street cleaning equipment. The likelihood of extensive use of porous pavement in some geographic areas, as discussed later in Section 1.2.2, may mean that detained water can seep into the ground instead of being discharged into the sewer system. This can be an important corollary advantage in watershort areas.

Problems with the use of parking lots for stormwater detention may be reduced to acceptable inconveniences by proper planning and design. Detention of stormwater on parking lots would not be favored by parking lot users because of the inconvenience that ponding imposes and its interference with vehicle access and movements. Steep slopes may be required to provide sufficient storage in a small area, resulting in water depths that might cause problems for people when walking to their vehicles. The steepness of the lot might be displeasing to some people, and such a lot might cause difficulty in walking for elderly and handicapped persons. The steep slopes could also cause problems of vehicle entry or exit because of reduced traction at times when ice forms on the paved areas.

There are two general forms of stormwater detention on parking lot surfaces. One form involves the storage of runoff in depressions constructed at drain locations. The stored water is drained into the sewer system slowly, using restrictions such as orifice plates in the drain. Proper design would restrict ponding to areas which will cause the least inconvenience to users of the lot. For example, the parking lot of a shopping center would have the ponding areas located in the least-used portions of the lot, allowing customers to walk to their vehicles in areas of no ponding except when the entire lot is filled with vehicles. Drainage of ponded water should be fairly rapid, as compared to rooftop storage, to prevent customer inconvenience. In most cases, the water would pond to a depth not to exceed 12" and the ponding area would most likely be drained within 30 minutes or less after the rainfall.

Another type of stormwater detention on parking lots consists of using the paved areas of the lot to channel the runoff to grassed areas or gravel-filled seepage pits. The flow then infiltrates into the ground. Soil conditions and the effects of siltation in reducing infiltration must be considered.[41]

Rooftop Storage. Horizontal rooftops are used in some areas for stormwater detention. Rooftops can provide storage which will not inconvenience pedestrians or motorists. Since such a facility is not usually visible from the ground, a rooftop detention facility is not unsightly and is not a safety hazard for children. However, potential problems of leakage, such as possible structural overloading, maintenance for removal of debris and ice, and the possibility that heavy rainfalls will overflow the top of the roof if drains become blocked, must be considered. Serious damage to the building and its contents could result if the facility were improperly designed or maintained.[42] Retarding runoff on flat roofs will result in greatly increased loads, in turn resulting in increased cost of construction. In some cases the savings from reduced storm drainage costs may make up this difference. Unfortunately, where retardation is most needed (large acreage single-story buildings) clear spans are also needed, so a small increase in load on the roof can result in large cost increases.[43]

A flat roof may be used as a retarding pond by delaying the flow of runoff to the downpipe. One approach employs a perforated strainer with limited capacity on the downpipe inlet. Provision must be made for an emergency overflow before water spills over the top of the roof parapet. Runoff must also overflow before the maximum permissible load on the roof is reached. Another approach uses gravel detention barriers across a flat roof.

On sloping roofs it is possible to construct runoff checks which effectively increase the time of concentration. However, as soon as the "findams" are full, the rate of runoff will be constant, provided that the storm continues at the same intensity. This technique may be useful to reduce runoff peaks of very short, very intense storms which may put an excess load on a storm drainage system. However, installation of these barriers may increase leaks and the retention of larger amounts of snow may result in excessive loads.[44]

Potential problems may be minimized by proper design, especially if storage is designed into the original plans and not provided later as an afterthought. Maintenance is a bit more difficult and will require periodic attention, especially in the autumn during and after the leaf-falling season. However, all horizontal roofs in urban areas need such maintenance and the added effort to maintain a roof designed to detain rain water should not be unreasonable. In many cases the roofs will be sufficiently high or the buildings will be located in areas where maintenance would not be a problem because debris would not accumulate enough to cause a blockage of the roof scuppers, gutters, or rain leaders.

The possibility of overflows is present with any roof structure, although it is more likely when stormwater is stored on the roof. One alternative usually required by building codes is the use of overflow drains and scuppers in the parapet wall. Proper maintenance and periodic inspection will reduce the possibility and hazards of overflows.[45]

3.2.2 Increased Infiltration on Site

This subsection deals with a number of measures designed to increase infiltration on site. The purpose of these techniques is threefold:

(1) To maintain runoff volumes and peaks from areas undergoing urban development at or near natural conditions.

(2) To maintain sufficient infiltration to shallow ground water in order to insure no retardation in the dry weather flow of streams.

(3) To maintain recharge of major aquifers at a level equivalent to those under natural conditions.

It should be stressed that increased infiltration of severely polluted stormwater runoff may cause ground water contamination. Therefore, the measures described here apply more to those areas still undergoing urban development rather than those areas where dense urban development already exists. The former group of areas represents a type of land use still in the process of formation and it is here that stormwater runoff pollution can be successfully contained through careful planning. At this stage, the volume and rate of runoff are increasing due to the encroachment of urbanization; yet the runoff itself is not so severely polluted. For this reason, the runoff may be used to recharge ground water in water short areas through the methods intended to increase infiltration which are described in this subsection. Where dense urban development is evident, as in the latter group of land uses, increased infiltration may cause ground water contamination. Here, where the flexibility of approach is limited, more corrective measures may be called upon, such as street sweeping and catch basin cleaning described in the previous section.

Several approaches are described: Dutch drains, porous paving--asphalt, precast concrete lattice blocks and bricks, seepage basin or recharge basin (single use), recharge basin (multiuse), seepage pits or dry wells, and other methods. As mentioned above, these approaches involve permanent measures, that is, measures which must be installed by the developer during the development process and which must remain in place after the development has been completed. However, a number of the measures might also be applied after development has been completed.

Dutch Drains. Dutch drains are gravel-filled ditches with an optional drainage pipe in the base. The purpose of Dutch drains is to reduce the volume of storm runoff and to reduce flood peaks by increasing ground infiltration. Dutch drains intercept sheet runoff prior to concentration as compared to infiltration ditches. This measure may be applied on any type of site where the permeability of the soil is sufficient or where seasonably high water tables are not anticipated. These drains may either accommodate the maximum flow for a 24-hour flood and thus avoid the need for a storm-drain system, or they may be designed to take less runoff, in which case they will only act as retarding devices as far as reduction of flood peaks is concerned.

Dutch drains enjoy the following advantages: they reduce the total volume of runoff and can reduce peaking effects of local floods; enhance groundwater supply; improve quality of vegetation on site by increasing available water in the ground; and result in a reduction in the size of storm drains required downslope of the facility. However, unless "at source" seepage facilities are either designed for large storms or incorporate some method of controlled runoff release, they may not effectively reduce flood peaks when one storm follows another so closely that all facilities are full. The drains, if possible, should be designed to overflow before their capacity is reached during intensive storms. Dutch drains are subject to clogging. In addition, Dutch drains do not eliminate the need for a storm drainage system downslope to take the overflow from exceptional storms. They do, however, significantly reduce the necessary size of this system.

Dutch drains may be used to collect runoff from roofs without gutters. The drains would run the entire length of the eaves and runoff would fall directly onto the surface of the Dutch drain, which may be bare gravel, grass, or occasionally, porous paving. A combination Dutch and French drain could also be used to ease the problem of maintenance. Sidewalks running alongside may also discharge into Dutch drains. Another application involves the use of Dutch drains in dividing strips between areas of impermeable paving to collect sheet runoff. These will usually be paved so as not to hinder the passage of traffic. Tile drains set at the base of Dutch drains and discharging into an overflow storm system will more effectively reduce flood peaks during intensive storms. Similarly, if the surface of Dutch drains has a longitudinal fall allowing runoff during excessively heavy rain, peaks will be lower. Dutch drains on well-drained soils may reduce the size of needed storm drainage facilities, resulting in a cost savings.[46]

Porous Paving--Asphalt. Porous pavement consists of a base course of crushed gravel with a surface course of porous asphalt concrete.[47] While still an experimental measure with limited application, porous pavement must be considered in this manual. Porous pavement is being studied as a means to: absorb rainfall where it falls, preventing runoff and combined sewer overflows and eliminating the need for treatment plants to handle stormwater; hold back stormwater surges; allow the water to percolate into the ground at its own rate, and/or store it for use; conserve water and land; avoid puddles in flat areas and provide adequate drainage without crowns and sloping; prevent accidents due to standing water; minimise damage to the environment; present a satisfying appearance; and provide a possible means of disposing of solid wastes by reuse of these materials for construction purposes.

Use of porous pavement will be practical only if it can meet the following criteria: it must be able to carry loads without damage, be able to survive freeze-thaw cycles and other weathering, be easy to repair and hard to damage; and be capable of absorbing all or most of the rainfall with provision for cleaning the pavement, should the pores become clogged. Porous pavement is competitive in cost with normal pavement when the cost of drainage facilities to service normal pavement is included. However, for parking lots and playgrounds, the cost of porous pavement is more than the cost of alternative pavement. Depending on the situation, though, porous pavement may create additional benefits: no standing water, reduced load in combined sewers, and restoration of water supply. Porous pavement is thus an atractive alternative in areas where the natural soil is free-draining. In all cases, the subbase design must take into account the moisture conditions that must be accommodated.

A roadway or parking lot could provide considerable water storage without interfering with normal usage and additional storage could be obtained cheaply by adding more base material. This water can then be allowed to drain naturally into the soil, depending on the soil permeability; or, if collected, it can be used elsewhere or routed into the sewer system. In any case, careful consideration must be given to the bearing capacity of the subbase to assure proper roadway support. Finally, groundwater movement may be restored to natural conditions, helping to replenish supplies.[48] Of course, other local factors must also be considered: geographic and temperature, surface and subsurface soil conditions, and the possibility of groundwater contamination.[48]

Porous pavement reduces the total volume of runoff from paved areas and can reduce the peaking effect of local floods and enhance the groundwater supply. Savings may be realized by reducing the need for storm sewers and curbs; pedestrians may also benefit since there would be no puddles. However, it has not been clearly established that the filtering effect of the subbase results in a significant improvment in the quality of runoff if polluted. Under certain circumstances the surface may become clogged, and its permeability would be reduced. Inadequate maintenance, rain on a frozen surface, and certain conditions during snowmelt may all result in runoff. Higher construction costs would be involved where curbs are necessary, and maintence costs may be high. The sizing of storm sewer systems is determined by ordinance in most municipalities. Porous paving is a relatively new development, and few jurisdictions permit its use. Where it can be used, however, regulations may not permit any reduction in the size of storm drains.[50]

Precast Lattice Blocks and Bricks. There are a variety of precast paving slabs which provide a hard surface and yet are porous to varying degrees. This measure can be applied only when the soil is sufficently porous to allow rapid drainage. Perforated slabs on a honeycomb base may be used to cover Dutch drains between areas of impermeable paving (making a lattice of permeable paving throughout a parking area). Brick strips incorporating tree pits may be used in a similar fashion.

The objective of this measure is to infiltrate precipitation "at source" prior to concentration. These materials have a number of important advantages, such as that grass can substantially cover the site; they are flexible and and can withstand a certain amount of movement; and when used as strips between asphalt, sections can be lifted to plant trees or place street signs, or even maintain utility lines underground. However, most of these materials are not as useful as porous asphalt paving, because they are expensive and difficult to lay, are not as permeable as asphalt, and in most cases do not give as good a walking surface. Therefore, they tend to be used in situations where porous asphalt pavement is not suitable, such as very formal "hard" areas, unstable areas subject to subsidence or heave, and areas where a grass-covered surface is desired.

Lattice concrete blocks may be used for parking areas where an "informal" grass surface is required but which must be sufficiently hard-wearing to withstand regular use. They may also be used for lining grass swales to provide erosion and sedimentation protection, and for grass ramps. Modular pavers are perforated bricks or bricks with lugs to control spacing, and may be used in areas where more wear is expected than for lattice blocks. Interstices and perforations should generally be kept free of vegetation. This paving type is used in more formal areas than lattice blocks for paving around trees, for dividing strips between impermeable paved surfaces, etc. This type is generally not a comfortable walking surface.

Precast concrete perforated paver may be laid over precast concrete lattice block for use in formal areas, especially where warping of large impermeable surfaces would be unsightly. This type may also be used as a strip cover for French drains between areas of impermeable surface. Concrete blocks may be lifted and the web and sand filter cleaned out if the percolation rate falls. Other porous paving types include a metal honeycomb covered by a butyl rubber mat, and bricks with two perforations through which metal rods are passed and the bricks separated by spacers.[51]

Seepage Basin or Recharge Basins (single use). The purpose of a seepage basin is to allow a large percentage of the annual rainfall to recharge a valuable aquifer. Runoff is collected in various storm drainage systems prior to being discharged into the basin. This measure is used principally on aquifer recharge areas but may also be used on any site where the water table is always over 48" below the ground surface. Recharge basins are extensively used in urban areas of Long Island to recharge ground water. Provided the soil is reasonably porous, a recharge basin can recharge large quantities of water in a short time without the use of much land.

Because basins are deeper than seepage areas they operate under a greater head and, therefore, are capable of recharging a greater volume of water per unit area in a given time. Seepage basins, then, require less land area than seepage areas. The seepage basin is generally regarded as a single-use facility, managed intensively for recharge. The basin must be fenced and regularly maintained and is often very ugly. Seepage basins need constant maintenance to ensure that porosity is not reduced. Where this does happen, it may be necessary to bore seepage holes or pits in the base. Unless fenced, seepage basins may be a safety hazard where more than 30" deep.

The sizing of the basin depends on the objectives to be served. If it is to recharge as much water as possible, it should be sized to take the maximum 24-hour rainfall from all paved areas. Almost certainly though, this is not economical; instead, it will likely be desirable to recharge most of the annual precipitation (except for the very large storms), which may be accomplished with a much smaller basin.

Recharge basins are mandatory on Long Island, where geologic conditions are favorable for aquifer recharge and where municipal supplies depend heavily on a sustained groundwater yield.[58]

Recharge Basins (multiuse). Wherever soils are relatively permeable and groundwater is not too close to the basin floor, recharge basins may be an effective means for aquifer recharge. They are often used primarily for disposal of storm drainage with recharge as a secondary benefit. This measure may be used effectively only where the aquifer outcrops at the surface (i.e. at aquifer recharge areas) or in areas where the aquifer is so shallow that the basin extends to the aquifer (or in some cases, where strata overlying the aquifer are very permeable and allow percolation of water to the aquifer).

When a recharge basin has benefits in disposing of stormwater as well as recharging the aquifer, it may be an economically attractive method of conserving groundwater resources. Often a recharge basin can be constructed as a borrow pit as part of a major construction project, e.g. a highway. This measure does not take advantage of the filtering effect of the soil, as in the case with recharge by irrigation; therefore, there is a risk of pollution where recharge water is of variable quality, such as with runoff. Basins are extremely susceptible to clogging unless recharge water is fairly free of sediment and the basin is maintained frequently.[59]

Seepage Pits or Dry Wells. Seepage pits collect runoff and store it until it percolates into the soil, but, unlike Dutch drains, they do not conduct water along their length when filled. Seepage pits may be used on all sites where the permeability of the soil is sufficient and where seasonably high water tables are not anticipated. Seepage pits may be designed to accommodate a maximum design frequency 24-hour storm, or they may be designed at least to allow infiltration of runoff at predevelopment levels. In this case a supplementary system of storm drains will be necessary to accommodate overflows.

If properly designed, seepage pits may reduce local flooding, enhance groundwater supply, and in some cases they may eliminate the need for storm drains or reduce the size of the required storm drains. A seepage pit will, provided the soil permeability is sufficient, accomplish the aim of increasing infiltration. However, unless very large, it may not result in a reduction of flood peaks. Seepage pits are more liable than Dutch drains to clogging by sediment, as runoff has more chance to collect solids before reaching the pit. Unless the seepage pit is designed to take the total amount of anticipated runoff for a design storm, some provision must be made for overflow. In order to have the maximum benefit in reducing flood peaks the pit should, in fact, overflow during intense storms before its capacity is reached. The maximum size of a pit should be sufficient to maintain infiltration at predevelopment levels. Such pits are usually filled with gravel or rubble, and sometimes may be cased.

The Board of Supervisors of the Montgomery County (Maryland) Soil Conservation District, who are involved in carrying out the county's sediment control program, adopted a policy in April 1971 to "encourage and assist in planning for the retention on and in the soil of the greatest possible percentage of annual precipitation including the use of ... infiltration devices (pervious surfaces on parking areas, dry wells, leaching pits, etc.)."[54]

Other Methods

Seepage beds dispose of runoff by infiltration into the soil via a system of drains set in ditches of gravel. These systems only reduce volume and speed of runoff and requires an overflow system. By increasing the time of concentration they may also reduce flood peaks slightly. This system may be used on all sites except those with periodically high water tables or where soil drainage is poor. This system may be used where the percolation rate does not allow the use of seepage pits.

Seepage beds provide distribution of water over a larger area than may be achieved with a seepage pit, resulting in less hazard of clogging. They may be placed under areas of paving if the bearing capacity of the pavement is not affected. Seepage beds allow groundwater recharge and are safer than infiltration basins. However, no filtering takes place by the topsoil although there will be some improvement of water quality as infiltration takes place. Should beds or ditches eventually become clogged with sediments, replacement of the entire system is necessary; therefore, maintenance of sediment traps must be frequent and, consequently, is very expensive.[55]

Multi-purpose seepage areas may be employed to allow a percentage of annual precipitation to seep into the ground, to store excessive runoff, and to provide for multi-purpose use of such a facility through careful design for recreational use, parking, or open space. This measure may be applied in all areas except those with periodically high water tables or where soil drainage is poor. Such facilities are useful in areas where open space is not needed for use at all times and when the alternative use is not necessary during a storm and for a period after. There will be a problem, for instance, in using overflow parking areas when there is a possibility of cars being left on the lot during a storm.

The recharge facility is designed for multi-use. Where a grass surface is used, there may be a significant improvement in the quality of recharged water due to the filtering effect. Because of the requirement for multi-use, though, the facility must have a higher rate of recharge and be shallower than single-use basins. It is often difficult to maintain porosity of multi-use areas, except when those are paved surfaces (porous asphalt).[56]

3.3 Erosion and Sedimentation Control Measures

Five major principles of erosion and sedimentation control may be identified:

- Keep disturbed area small;
- Stabilise and protect disturbed areas as soon as possible;
- Keep stormwater runoff velocities low;
- Protect disturbed areas from stormwater runoff; and
- Retain sediment within the site area, and by doing so, control other pollutants, such as heavy metals.

The development should be made to fit the site with a minimum of clearing and grading. Existing cover should be retained and protected whenever possible. Critical areas, such as highly erodible soils, steep slopes, stream banks, and drainageways, should be identified and protected. When earth change and removal of vegetation are necessary, keep the area and duration of exposure to a minimum. The development should be phased so that only areas which are actively being developed are exposed. All other areas should have a good cover of vegetation or mulch.

Disturbed areas may be stabilised by mechanical (or structural) methods and vegetative methods, or by combinations of these approaches. The removal of existing vegetative cover and the resulting increase in impermeable surface area during development will increase both the volume and velocity of runoff. These increases must be considered when providing for erosion control (measures to increase infiltration and reduce runoff have been presented in Section 3.2). Slope changes should be designed to keep slope length and gradient to a minimum. Short slopes, low gradients, and the preservation of vegetative cover can keep runoff velocities low, minimising erosion hazards.

Measures can be utilised to prevent water from entering and running over disturbed areas. Sediment can be retained by either filtering runoff as it flows, or by detaining sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, though, is to prevent erosion. Erosion control measures serve to:

- Divert runoff from exposed soils and other vulnerable areas;
- Safely convey runoff, either in surface or enclosed drainage systems by:

    -- controlling runoff velocity
    -- insuring that all surface channels and outlet points are adequately drained;

- Stabilize exposed surface areas; and
- Control the volume and velocity of runoff discharge from the development area.

These measures can be either vegetative or mechanical. Vegetative measures include the planting of grasses and other vegetation to stabilize inadequately protected soil surfaces. Mechanical measures include control techniques which involve the building of structures (for example, check dams, sediment basins, diversions) or the operation of equipment to achieve compaction or surface roughening. Vegetative and mechanical measures may be either temporary or permanent.

Sedimentation control serves to:

- Detain runoff for a period of time to allow soil particles which are in suspension to settle out;
- Filter runoff as it flows; and
- Intercept runoff containing sediment before it leaves the development site.

Sedimentation control measures, like erosion control measures, may be either vegetative or mechanical.

Vegetative and mechanical erosion and sedimentation control measures may be classified either as temporary or permanent, depending on whether or not they will remain in use after development. Annual grasses, mulches, and netting, for example, are temporary control measures, although they may remain in place after development has been completed. The planting of perennial grasses, sod, shrubs, and trees are permanent vegetative control measures. Temporary measures generally serve for one year or less. Permanent vegetative stabilization will be required on all developments

Where the development is a long-term project, permanent measures installed in the first phase of development will serve the entire term of development. On large projects, where significant increases in runoff volume and velocity are inevitable, permanent structural measures for controlling the release of runoffs to off-site and downstream areas will be necessary. Where even limited amounts of erosion and/or sedimentation would do significant damage, measures to trap sediment and control runoff will be necessary. Temporary measures are used in the construction process. In some cases, temporary measures may be planned into a development in such a way that they become permanent as the completion of the various phases of the development occurs. For example, sediment basins can be converted to permanent ponds which become valuable site amenities. Figure 3.1 illustrates a number of temporary erosion and sedimentation control measures, while Figure 3.2 indicates that a number of temporary measures may become part of the permanent development.

The following subsections cover six types of erosion and sedimentation control measures:

- Vegetative measures;
- Diversion measures and slope drains;
- Mechanical slope stabilization techniques;
- Stream bank stabilization techniques;
- Design and stabilization of surface drainageways; and
- Other erosion and sedimentation control measures.

Figure 3.3 summarizes these various control measures and indicates their applicability to seven typical problem areas associated with erosion and sedimentation.[57]

The control of erosion and sedimentation is, by and large, the product of long years of research done by the Soil Conservation Service. Before a comprehensive program is embarked upon, it is suggested that the local official contact the SCS agent in his area.

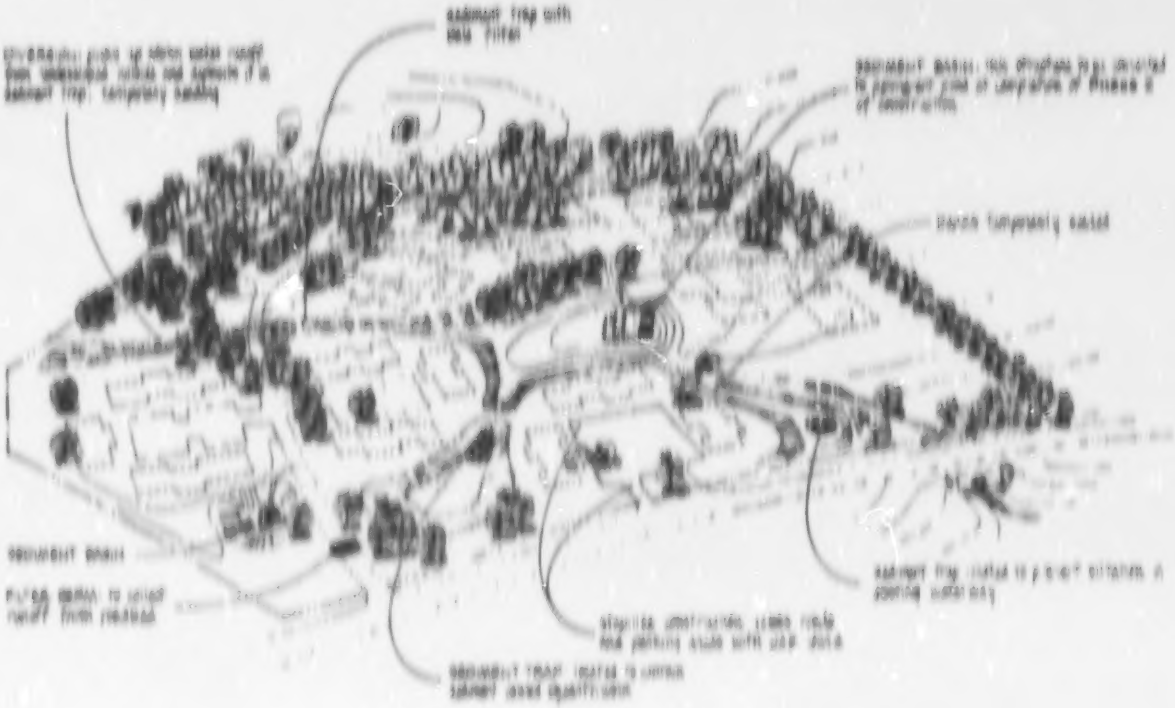

sediment trap with
filter
sediment basin
ditch temporarily seeded

Figure 3.1: Temporary Control Measures Used During Construction

Source: Beckett Jackson Raeder Inc., op. cit., p. 18.

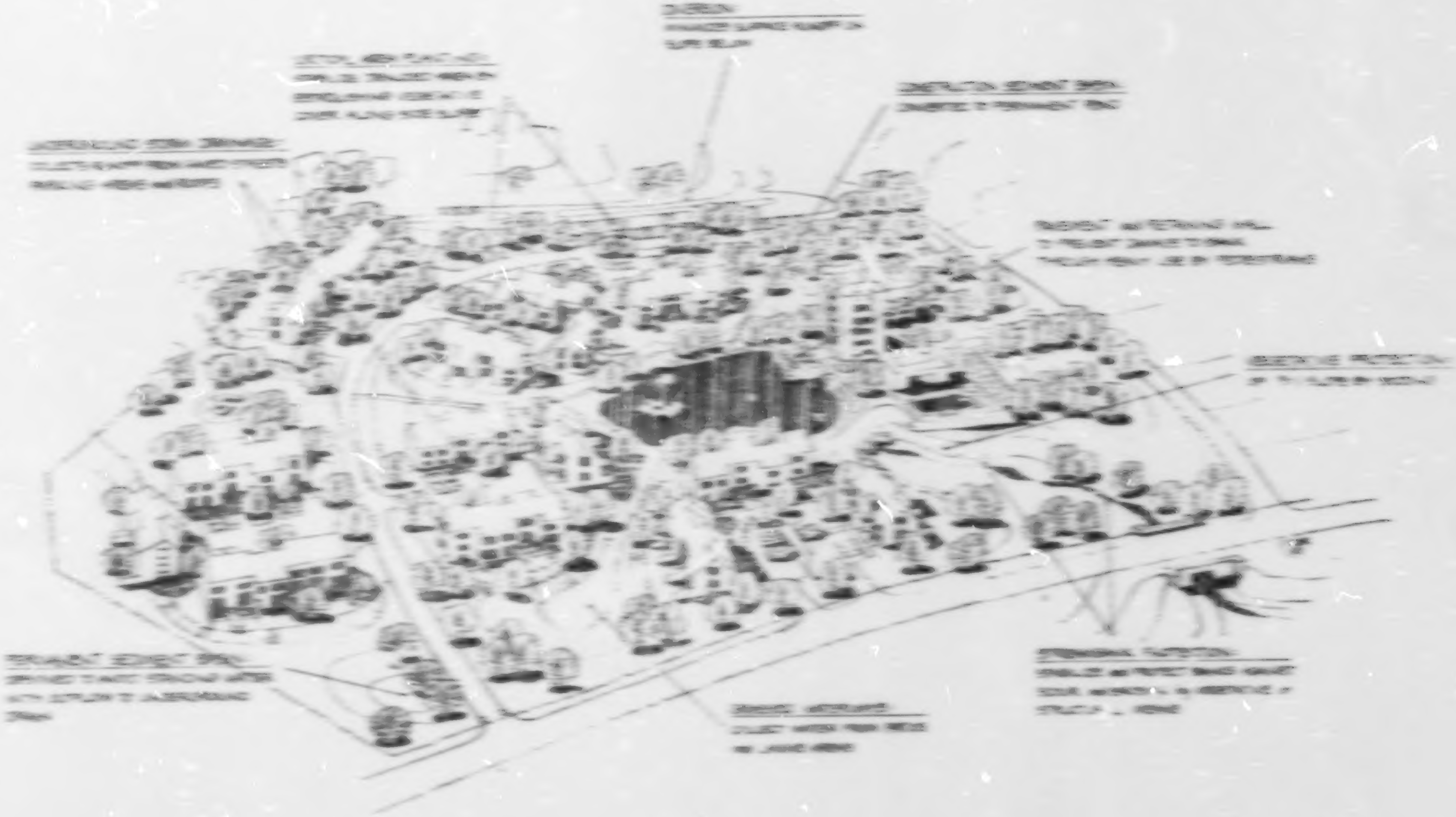


Figure 3.2: Many Temporary Measures Can Be Made Permanent

Source: Beckett Jackson Raeder Inc., op. cit., p. 19.

Figure 3.3 Control Measures and Problem Areas

	● INDICATES APPLICABILITY OF A SPECIFIC CONTROL MEASURE TO ONE OR MORE OF THE SEVEN PROBLEM AREAS Control Measure	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
VEGETATIVE MEASURES	Minimization of stripped areas	●				●	●	
	Grubbing omitted	●				●		●
	Conservation of topsoil	●				●	●	
	Temporary mulching and/or seeding	●		●		●	●	●
	Seeding	●		●		●	●	●
	Mulches	●				●	●	
	Seeding with mulch and/or matting	●		●			●	●
	Hydroseeding	●				●	●	●
	Sodding	●		●		●	●	●
	Bio-technical protection of steep slopes	●						
DIVERSION MEASURES AND SLOPE DRAINS	Diversion berm	●					●	●
	Interceptor berm	●	●					●
	Diversion ditch	●					●	●
	Berm and ditch	●					●	●
	Slope drain	●						
MECHANICAL SLOPE STABILIZATION	Selective grading and shaping	●				●	●	●
	Roughened surface	●				●		
	Compaction	●				●		
	Benches or terraces	●					●	
	Retaining wall	●						●
	Seepage control	●						●
STREAM BANK STABILIZATION	[illegible]		●					
	Deflectors and jetties		●					
	Revetments		●					
	Bio-technical protection of stream banks		●					
	Check dams		●					
	Weir		●					
SURFACE DRAINAGEWAYS	Bare channels			●				
	Grassed waterways			●				
	Lined channels			●				
	Grade control structures		●	●				
	Sediment trap		●	●				
	Sediment basin		●	●	●			
OTHER MEASURES	Filter inlet				●			●
	Aggregate cover					●		
	Curb and gutter					●		●
	Windbreak					●		
	Filter berm	●	●					●
	Traffic control at construction haul					●		

Source: Barrett Jackson Raeder Inc., op. cit., Figure 2

3.3.1 Vegetative Measures

Potential erosion is minimized by providing a protective vegetative cover, since this vegetation shields the soil from the impact of falling rain, slows the velocity of the runoff, maintains the soil's capacity to absorb water, and holds soil particles in place. By limiting and staging the removal of existing vegetation, and by decreasing the area and duration of exposure, soil erosion and sedimentation can be significantly reduced. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential, such as erodible soils, steep slopes, drainageways, and stream banks.[58]

This subsection describes a number of temporary and permanent vegetative measures to reduce erosion and sedimentation, both during the construction phase and after development has been completed. The following vegetative measures are considered: minimization of stripped areas, grubbing omitted, conservation of topsoil, temporary seeding and/or mulching, seeding, mulching, seeding with mulch and/or matting, hydroseeding, sodding, and bio-technical protection of very steep slopes. From a water quality aspect, reducing the contribution of sediment to runoff leads to a reduction in suspended solids concentration and other materials which adhere.

Minimization of Stripped Areas. The developer may reduce the area stripped of vegetation at any one time by careful time-phasing of the development. The economies of scale in earthmoving costs and the mobilization costs of large earthmoving machines, however, often dictate that all earthmoving is done at one time. When large areas must be left bare for up to 12 months and final grading cannot be carried out, stripped areas should be mulched and/or seeded.[59]

Grubbing Omitted. Grubbing is the process of removing roots, stumps, and low-growing vegetation. If this process is omitted, besides yielding a cost saving, new sprouts are provided, the existing root mat system is retained, wind fall is reduced at the forest edge, and equipment entrance is discouraged.[60]

Conservation of Topsoil. On all sites except those in wetlands and along creeks and streams, topsoil should be stripped to a depth of 9" from all areas which are to be disturbed and which are not to be covered by buildings or pavements. Topsoil must be stockpiled and respread to ensure a rapid vegetation growth following restoration. Unless carefully located, though, storage banks of topsoil may obstruct site operations and result in double handling. These mounds may sometimes be used as baffles to reduce noise, dust, etc., reaching neighboring properties, thus minimising complaints. If they are to be in position for more than six months, seed with a temporary seed mix. A shallow trench around these mounds made with a bulldozer blade will prevent soil eroded from mounds from washing onto adjacent property or into drainage channels. Topsoil may also be stockpiled above borrow areas to act as a diversion.

The conservation of topsoil is in the developer's interest as it results in more rapid and health grass growth, which not only prevents erosion, but also improves the appearance of the development. In some European countries the conservation of topsoil is mandatory. Where such measures are mandatory in this country, however, they are often ineffective due to failure to inspect installation.[61]

Temporary Mulching and Seeding of Stripped Areas. All areas which will remain open for more than six months on steeply sloping or highly erodible sites should be mulched and/or seeded. On other sites, only those areas larger than one acre must be mulched and/or seeded. (Note: the protective vegetative cover should be replaced immediately, however, in certain critical areas. Any disturbed area along a creek or stream should be sodded, while disturbed areas in wetlands should be reinstated with local plant material.) This is a relatively inexpensive form of erosion control offering rapid protection to open areas, but should be used only when final grading and seeding is not possible. Vegetation will not only prevent erosion, but will also trap sediment in runoff from other parts of the site. As temporary cover crop is sown on subsoil in most cases, growth is often poor unless heavy applications of fertiliser and lime are made while seeding. Once seeded, areas cannot be used for heavy traffic.[62]

Seeding. Standard seeding techniques provide an inexpensive and very effective measure for preventing erosion and sedimentation. Seed is drilled or broadcast either mechanically or by hand. A cultipacker or similar tool is used after seeding to make the seedbed firm and to provide seed covering. The proper timing of seeding, mulching, and watering is important for areas seeded in this manner. As soon as slopes are brought up to final grade, permanent vegetative stabilisation measures should be initiated. The selection of the appropriate plant materials for permanent stabilization should be based on a consideration of the following factors: soil and climate conditions; duration, quantity, and velocity of runoff; time required to establish cover; maintenance requirements; and site use. Grass is the least expensive and most effective material for permanent protection of eroding soils. Grass can be successfully established if certain basic requirements are met: proper seeding mixture is selected for the site; seeding dates are observed; area to be seeded is covered with topsoil; proper seedbed preparation and planting methods are used; adequate fertilizer is provided; and protection from wind and water erosion is provided during establishment.[63]

Mulches. Mulch is used after permanent seeding as well as before seeding to protect exposed areas for short periods. Mulches protect the soil from the impact of falling rain, slow the velocity of runoff, and increase the capacity of the soil to absorb water. Mulches hold seeds in place, preserve soil moisture, and insulate germinating seeds from heat and cold. Many types of mulch are available: straw, woodchips, wood fiber mulch, chemical mulch or soil stabilizer, excelsior mats, and other materials are used. Most mulches can be anchored. Asphalt emulsions can be used, as well as netting made of jute, fiberglass, or plastic. Another alternative is to disc the mulch just enough to anchor it into the earth.[64]

Mulched areas should be checked periodically, especially following severe storms, when damaged areas of mulch or tie-down material should be repaired.[65] In some counties chemical stabilizers are considered a mulch, specified in the county erosion control handbook.[66] Seeded area protection by netting or matting is often considered as a substitute for mulching. An example is the erosion-siltation control handbook produced by Fairfax County, Virginia, which is legally supported by county code amendments.[67]

Seeding with mulch and/or matting. Mulch and/or matting facilitates the establishment of vegetative cover and is effective for drainageways with low velocity. As mentioned above, mulches protect the soil from the impact of falling rain, slow runoff velocity, increase the capacity of the soil to absorb water, hold seeds in place, preserve soil moisture, and insulate germinating seeds from temperature extremes. Areas may be stabilized with seed alone, mulch alone, or both seed and mulch, depending upon site conditions and projected use of the area.

Hydroseeding. In hydroseeding, a mixture of seed, fertilizer, and water is sprayed on the slope. A mulch and a mulch tacking agent may also be applied. This method is effective on large areas.[68] Areas inaccessible to agricultural machinery may be easily seeded, but specialized equipment is required. If hydroseeded, accelerated germination during dry conditions may require irrigation later to sustain growth.[69]

Sodding. Sod strips are laid on the slope and in this way instant cover is provided. Sod should be placed on a prepared bed and pegged on steep slopes. Watering is important. This method of stabilization is effective and is often used on steep slopes, where seed may be difficult to establish. Sod is easy to place and may be repaired if damaged.[70] Sod can be placed at any time of the year provided that soil moisture is adequate and the ground is not frozen. Good quality sod free from weed species may be difficult to obtain. If laid in unfavorable season, by midsummer irrigation may be required. This also applies to very droughty sandy soils. Sod is heavy and handling costs are high.[71]

Bio-technical Protection of Very Steep Slopes. Alternative measures may be applied to very steep slopes, cut and fill banks, and unstable soil conditions that cannot be stabilized through seeded vegetation. Vegetation reduces sheet erosion on slopes and impedes sediment at the toe of slope. Where soils are unstable and liable to slip due to wet condition, utilization of soil moisture by vegetation can reduce the problem. Shrubs and trees shelter slopes against the impact of rainstorms and the humus formed by decaying leaves further helps to impede runoff. Mechanical measures help to stabilize soil long enough to allow vegetation to become established. Sod walls or retaining banks may be used to stabilize terraces. Sod is piled, tilting slightly, toward the slope and should be backfilled with soil and compacted as soon as they are built up. Timber frame stabilization involves construction of timber frames on slopes, filled with topsoil, and covered with straw; covering the straw with netting; and planting ground cover plants through the straw into the topsoil. Woven willow whips may be used to form live barriers for immediate erosion control. Berm planting and brush layers may also be employed. These techniques are considerably more expensive than conventional slope stabilization techniques. Adopted standards for erosion and sediment control by the state of Maryland include a listing of plants for critical area stabilization and ground covers, vines, shrubs, and trees. Standards also give reference to applicable resource areas, site conditions required, light preference, height, spread, spacing, time to form cover, size limitations, etc.[72]

The following table lists effectiveness of various types of ground cover on erosion loss at construction sites.[73]

Kinds of Ground Cover	Soil Loss Reduction Related to Bare Surfaces (Percent Effectiveness)
*Seedlings	
Permanent grasses	99%
Ryegrass (perennial)	95
Ryegrass (annual)	90
Small grain	95
Millet & sudangrass	95
Field bromegrass	97
Grass sod	99
Hay (2 tons/acre)	98
Small grain straw (2 tons/acre)	98
Corn residues (4 tons/acre)	98
Wood chips (6 tons/acre)	94
**Wood cellulose fiber (1.75 tons/acre)	90
**Fiberglass (1500 lbs/acre)	95
**Asphalt emulsion (125 gal/acre)	98

*Based on full established stand

**Experimental - not fully established

Source: County of Fairfax, Virginia. Erosion-Siltation Control Handbook. August 1972.

Minimizing erosion on site and limiting the amount of sediment being carried by runoff may benefit the developer by eliminating the need for regrading due to erosion and reducing the probability of damage claims by downstream landowners. Once established, vegetative cover will also greatly improve the aesthetic appearance of the development. Vegetative erosion and sedimentation control measures may be classified as either temporary or permanent depending on whether or not they will remain in use after development. Annual grasses, mulches, and netting, for example, are temporary control measures although they may remain in place after development has been completed. The planting of perennial grasses, sod, shrubs, and trees are permanent vegetative control measures. Temporary measures generally serve for one year or less. Permanent vegetative stabilization will be required on all developments.[74]

3.3.2 Diversion Measures and Slope Drains

Erosion and sedimentation resulting from runoff over slopes exposed during development may be reduced by using diversions to intercept runoff and divert it from the slope face. Such diversions may consist of a berm, a ditch, or a combination of a berm and ditch, and may be bare channels, vegetatively stabilized channels, or channels lined with a hard surface material. The following factors should be considered in design of diversion measures: the amount of runoff to be diverted, the velocity of runoff in the diversion, and the erodibility of the soils on the slope to be protected and in the diversion itself.

Diversions concentrate the volume of surface runoff and, as a result, also increase its erosive force. It is important to plan in advance for the disposal of runoff collected in diversions. Runoff must be released onto a stabilized area to reduce its erosive potential. In some cases this can be simply achieved by gradually reducing the gradient of the diversion channel. Diversions may also be used at intervals along the slope face to reduce slope length and may be used to collect runoff from a construction site and divert it to a sediment retention trap or pond.[75]

Where the runoff cannot be satisfactorily disposed of by conveying it laterally it can be drained over the face of the slope itself, employing a slope drain, either on the surface of the slope or below the surface. At the slope drain outlet energy dissipators are frequently required in order to reduce erosion problems by slowing the velocity of the runoff.[76]

This subsection presents a number of temporary and permanent measures to reduce erosion and sedimentation, including the following: diversion berm, interceptor berm, diversion ditch, berm and ditch, and slope drains. Temporary measures must remain in place until the slope has been permanently stabilized, but several of these measures may be incorporated in the permanent drainage system.

Diversion Berm. Diversion berms, or diversion dikes, are small ridges of soil constructed at the top of cut or fill slopes to divert overland flow from small areas away from newly constructed, unstabilized, or unprotected slopes. They are normally used as temporary or interim measures, but may sometimes be appropriate as permanent installations.[77] Diversion berms collect and direct runoff to prepared drainageways and may be placed as part of normal construction operations.[78]

Erosion reducing structures, such as diversion berms, interceptor berms, and sodded ditches, are normally employed at a rate of 165 feet per acre, reducing potential erosion by about 50%. High rate usage of these measures (over 165 feet per acre) may reduce erosion by 60%.[79] As the costs of diversion berms may range from $1 to $5 per linear foot, the cost per acre will vary from $165 to $825 per acre for diversion berms, at a rate of 165 linear feet per acre.[80]

Interceptor Berm. An interceptor berm, or interceptor dike, is a temporary ridge of compacted soil constructed across a graded right-of-way, reducing erosion by intercepting runoff and diverting it to temporary outlets where it can be disposed of with minimum erosion. Interceptor berms are usually used across graded rights-of-way that are not subject to vehicular traffic. Design details and costs of interceptor berms are approximately the same as those of diversion berms.[81]

Diversion Ditch. A diversion ditch collects and diverts runoff to reduce erosion potential and may be incorporated into the permanent drainage system.[82] The design of temporary drainage channels is basically similar to the design of permanent channels and must consider such aspects as capacity, cross section, and design velocity. As mentioned above, diversion ditches may be bare channels, vegetatively stabilized channels, or channels lined with a hard surface material.[83] The cost of sodded diversion ditches is approximately $825/acre.[84]

Berm and Ditch. A temporary diversion may be formed by constructing a channel and a ridge, usually across sloping land, to convey runoff laterally at a reduced velocity to a safe discharge point.[85] Such a diversion measure may also be used at intervals across the slope face to reduce effective slope length.[86]

Diversions and slope drains may be employed to divert runoff away from critical areas during construction, in order to minimize the erosion that would result from runoff crossing highly susceptible areas. A system of temporary channels prevents siltation in partially completed storm drainage systems. An efficient temporary drainage system minimizes the delays caused by severe storms during the construction period and minimizes the amount of regrading, etc., necessitated by erosion during the construction period. Some of the above techniques are temporary in nature and the removal of these measures will entail some costs, as well as additional disturbance and possible minor damage to permanent facilities. Diversions may also increase seepage which may cause soil instability.

Temporary diversions and slope drains are especially needed in road construction projects. Standard specifications of the Delaware Department of Highways and Transportation (January 1, 1974) specify that "slope drains may be constructed of pipe, fiber mats, rubble, Portland cement concrete, bituminous concrete, plastic sheets, or other material acceptable to the engineer that will adequately control erosion." The Washington County, Maryland, Erosion and Sediment Ordinance (1971) requires provisions for temporary measures and a timing schedule. The adopted standards and specifications for soil erosion and sediment control in urbanizing areas of the State of Maryland include detailed specifications for diversion dikes and interceptor dikes.[87]

Figure 3.4 illustrates a number of diversion measures.

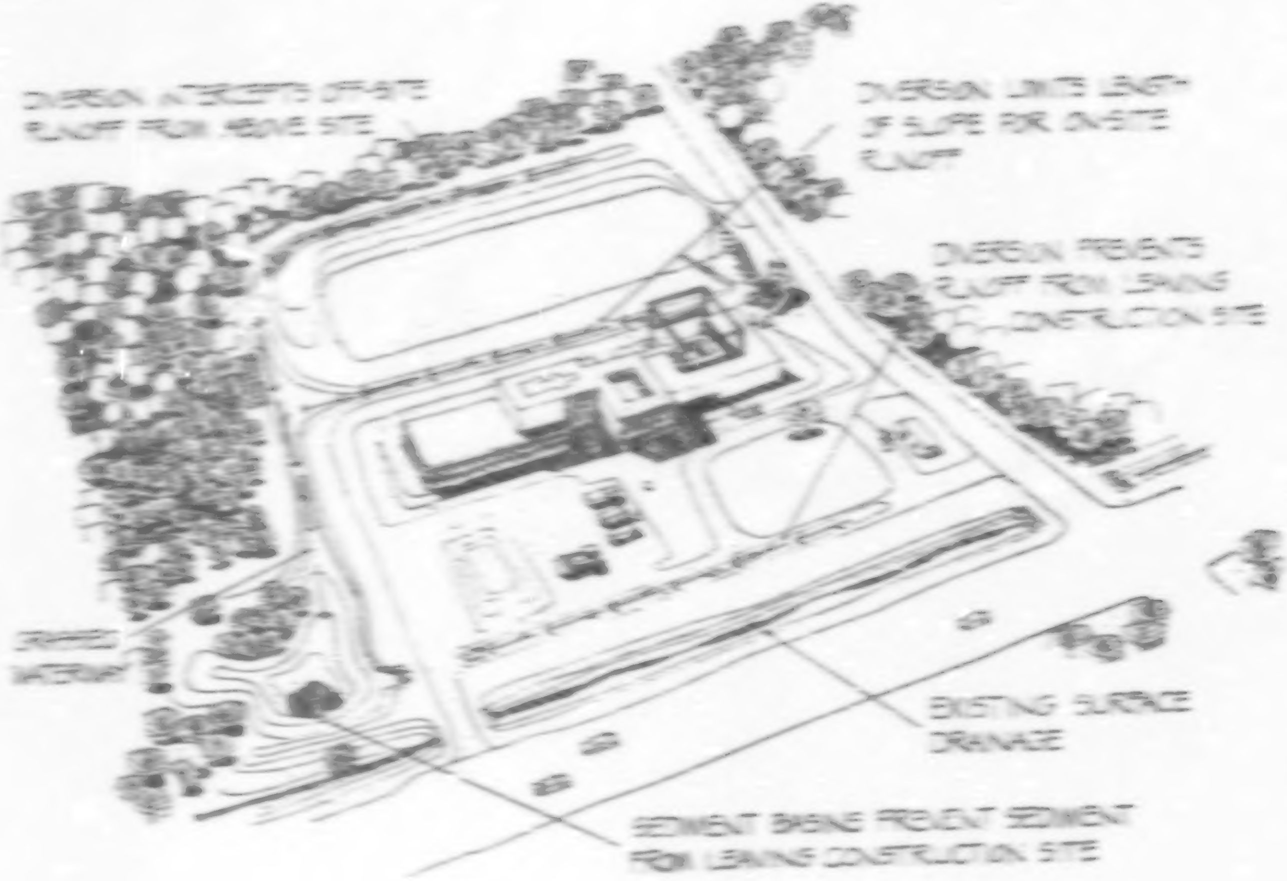

DIVERSION INTERCEPTS OFFSITE
RUNOFF FROM ABOVE SITE
DIVERSION LIMITS LENGTH
OF SLOPE FOR ONSITE
RUNOFF
DIVERSION PREVENTS
RUNOFF FROM LEAVING
CONSTRUCTION SITE
GRASSED
WATERWAY
EXISTING SURFACE
DRAINAGE
SEDIMENT BASINS PREVENT SEDIMENT
FROM LEAVING CONSTRUCTION SITE

Figure 3.4: Diversion measures

Source: Beckett Jackson Raeder Inc., op. cit., p. 21.

3.3.3 Mechanical Slope Stabilization Techniques

Mechanical slope stabilization techniques involve building structures (benches or terraces, retaining wall) or operating equipment to achieve compaction or surface roughening. Selective grading and shaping may be considered to minimize erosion. Seepage control may be required on cut slopes. Such measures will reduce erosion and sedimentation resulting from runoff flow over slopes.

Selective Grading and Shaping. One way to stabilize slopes is to reduce their gradient. The selection of the appropriate grade for cut and fill slopes should be based on a number of factors: the stability of the soil, its drainage characteristics, and its erodibility. The type of vegetative cover and the type of maintenance will determine the degree of slope allowable.[88]

Roughened Surface (Cultivation). During the construction period, areas may be bare for periods too short to make use of temporary mulches or cover crops. In these cases, careful cultivation can greatly reduce the volume of sediment generated on these areas.[89] If slope surfaces are left rough, this can help to reduce velocity and increase infiltration rates. Rough slopes also hold water, seed, and mulch better than smooth slopes.[90]

Careful attention to cultivation technique will pay the developer since it is one of the cheapest and simplest methods of erosion control. This technique may be readily incorporated into a development and is generally used by field supervisors on an as-needed basis. No great additional construction costs are incurred, since the measure makes use of existing equipment and personnel, nor are there maintenance costs involved in this interim measure.[91]

Compaction. On fill slopes compaction may be a major factor in erosion control. In addition to other compaction controls required by the nature of the project, the minimum criterion recommended for successful erosion control on fill slopes is to compact the uppermost one foot of fill to at least 85% of the maximum unit weight (based on the modified AASHO compaction test). This is usually accomplished by running heavy equipment over the fill. Formal testing might not be required.[92] Compaction helps hold the soil in place, making exposed areas less vulnerable to erosion.[93]

Benches or Terraces. Benches or terraces may be employed to reduce the slope length in critical areas. This measure may accomplish two objectives: to modify the form of a steep slope to minimize the erosion potential of runoff originating on the slope; and to control runoff from elsewhere so that it can pass down the slope in a protected channel or be diverted so that it bypasses steep slopes. Benches check the flow of runoff and collect sediment. Runoff may be diverted along the bench to increase the distance of overland flow. Benches also provide access for maintenance and hydroseeding. Serrated slopes lower the velocity of runoff, increase the distance of overland flow and reduce the hydraulic gradient, along with holding moisture and minimizing sediment.

Benches and serrated slopes may significantly increase cut and fill costs and cause sloughing where excessive water infiltrates unstable soils. Slope length and the need for benches or terraces is a particular concern in highway construction. Standard specifications of the Delaware Department of Highways and Transportation handle the problem this way: "The engineer will limit the area of excavation, borrow, and embankment operations in progress commensurate with the contractor's capability and progress in keeping the finish grading, mulching, seeding, and other such permanent pollution control measures current in accordance with the accepted schedule. Should seasonal limitations make such coordination unrealistic, temporary erosion control measures shall be taken immediately to the extent feasible and justified."[94]

Retaining Wall. Retaining walls should be used to reduce extreme slope gradients. For example, if the final grade of a slope is too steep to permit the establishment and maintenance of vegetation, retaining walls can be used to reduce the slope's gradient. Retaining walls can also be used to allow for the retention of existing mature vegetation. The cost of building retaining walls is often justified because of the maintenance costs that are saved on areas that would be difficult or impossible to stabilize otherwise.[95]

Seepage Control. On cut slopes ground water seepage can cause erosion problems. Seepage causes piping and soil slippage. Water seepage coming out of the face of the slope should be intercepted by a properly designed drainage system. A diversion permits percolation of surface runoff, contributing to underground seepage. Such seepage may be reduced by providing a sand trench under a diversion at the top of a slope and a sand layer under the surface of the slope, along with a perforated tile or interceptor drain at the toe of the slope.[96]

Again, reducing erosion on slopes will benefit the developer by eliminating the need for re-grading. Reducing the slope length may also facilitate the establishment and maintenance of vegetative cover.

3.3.4 Stream Bank Stabilisation Measures

Stream bank erosion is a natural phenomenon but can become a problem when it is accelerated due to increased runoff, and where it can no longer be tolerated due to urban riparian uses. The erosive and transporting power of a stream increases with increasing velocity, turbulence, depth of flow, and gradient, while the ability of a stream to erode its banks varies inversely with the amount of sediment it already is carrying, including both bedload and suspended material. The following events may result in problems of stream bank instability: realignment of the channel, an increase in runoff volume, sedimentation of the streambed, and constriction of the channel.

Often as part of urban development stream channels are realigned and, almost invariably, shortened. This automatically results in a steeper stream gradient which increases the flow velocity and erosive capacity. The stream will compensate for this increase in energy by trying to meander, cutting laterally, or eroding its bed.

Urban development of a drainage basin will greatly increase the volume of water which a stream must handle. Not only will the extent of the floodplain be larger, but the stream will overflow its bankful stage more often. It is at or near the bankful stage that most damage is done to stream banks. Thus the increase in runoff will worsen stream bank erosion, although the duration of flow at bankful stage may be shorter due to more rapid runoff from urbanised areas.

Stream channels may become partially clogged with sediment which often originates from upstream development activities. This reduces the capacity of the channel and the stream tries to compensate for the loss by eroding laterally. A bridge, culvert, landfill, fallen tree, etc., may cause local channel constriction leading to erosion. In the case of a bridge where the stream may be constricted laterally by abutments, the velocity may be increased resulting in scouring of the streambed beneath the bridge (which could cause failure of the abutments). Lining of the channel bed under the bridges is common practice, but this may increase velocity and constrict the channel vertically. This may result in a plunge pool where the lining ends and scouring above the constriction. If scouring of the streambed is limited, scouring of the banks often occurs where revetments end.

A culvert effectively constricts a channel, both vertically and laterally, and so protection from scouring at both ends is vital.

The more stable a stream, generally the greater its potential for fishing, wildlife, and recreation. However, stabilisation of small sections of stream channel can result in serious erosion problems upstream and downstream. Stream bank stabilisation is generally expensive and should be limited to critical areas. Ideally, the stream should be allowed as much freedom as possible to modify its channel and achieve new stability but should be watched so that prompt action may be taken where and where it is appropriate.

The center line of a stream is frequently a property boundary. Therefore, a shifting channel may lead to legal disputes. The need for channel protection often arises from development activity upstream. A riparian owner adversely affected should seek legal advice on whether or not he can claim compensation for damages. The action of lining of realigning a stream channel may cause more severe instability of the stream channel for downstream and sometimes upstream riparian owners. The possibility of causing damage to neighboring riparian owners should, therefore, be carefully considered before undertaking stream improvements.[97]

The maintenance of existing vegetation on stream banks is a fundamental principle of erosion and sedimentation control. Stream bank vegetation serves to stabilise the soil, slow runoff and dissipate its erosive energy, and to filter sediment from runoff.[98] Appropriate vegetative stabilisation measures were discussed in Section 3.1.1. This subsection describes a number of structural measures to prevent erosion of stream banks: falls, deflectors and jetties, revetments, biotechnical methods, check dams, and weirs.

Falls. A fall is usually installed to dissipate excessive energy in a stream or channel where the steepness of the gradient is causing high velocity flow. This often results from straightening a stream's course. Falls in perennial streams should be designed by a qualified engineer; they may be constructed of dumped rock, gabions, or concrete. In all cases the structure must be protected adequately, as the tendency will be for a plunge pool to develop at this point which could undermine the structure. The dam need not be impermeable. Where loose rock is used it must be of sufficient size to withstand streamflow and, consequently, it is usually grouted or used in gabions to form a massive structure. Falls may reduce the need for channel lining and create areas of still water which often increase the stream's recreational value.[99]

Deflectors and Jetties. Where vegetation will not provide sufficient protection banks may be protected with revetments and deflectors, as well as other mechanical measures. Deflectors and jetties are used to deflect streamflow away from an eroding bank or to prevent meandering of a stream, thus encouraging the stream to increase its channel capacity by scouring its bed rather than by lateral cutting.

Deflectors and jetties cause areas of comparatively still water where sediment loads are precipitated, increasing the stream's recreational value. The buildup of sediment against the bank allows it to be stabilized without planting. However, deflectors will considerably restrict the channel capacity and should be used only where the stream's natural tendency to compensate for this by scouring either the bed or the opposite bank will not cause a problem.[100]

Revetments. Revetments, which cover the stream banks, are commonly used where sharp bends or constructions in the stream channel (such as culverts, bridges, or grade control structures) occur.[101]

Choice of a revetment type will depend on a survey of streamflow characteristics, soil type, etc., but often the *USGS* can provide data for discharge and velocity characteristics for streams of similar size for more accurate revetment and lining design.

Biotechnical Methods. A combination of vegetative and mechanical means may be employed to provide protection of critical sections of stream bank. These approaches should be used in streams with high flow velocity where the flow/soil conditions exceed the stabilizing effect of purely vegetative channel protection. Mechanical materials provide for interim and immediate stabilization until vegetation takes over. Once established, vegetation can outlast mechanical structures requiring little maintenance while regenerating itself; their use also entails aesthetic benefits and increased wildlife propagation. These measures do involve slightly higher initial cost than purely vegetative measures, and may also require professional assistance. While the methods described are effective, a complete knowledge of soils, hydrology, and other physical data is required to design measures that will adequately solve the problem and stand up to the test of time.

Reed berms consist of a combination of reeds and riprap, and may be employed to break wave action and reduce erosion of banks by currents. Willow jetties can be constructed at the water level to stabilize a cutback by deflecting the current and encouraging deposition of sediment. Willow gabions may be used when a hard-edged effect is desired to deflect the eroding flow of water. Piling revetment with wire facings is especially suited for the stabilization of cutbanks with deep water. In the lower riparian zone (open floodway) bank stabilization should be concentrated on critical areas only. Willow branch matt revetment may also be employed to stabilize stream banks.

A recommendation to change the New Castle County (Delaware) Drainage Code includes the following set of recommendations regarding stream bank stabilization: "Where the flow/soil conditions exceed the stabilizing ability of vegetation, then as a second option a combination of vegetative and mechanical means of stabilization (biotechnical methods of stream bank stabilization) will be explored, and as a third and least desirable option, a straight mechanical method will be explored."[102] Costs vary according to the local availability of labor. However, there are practically no maintenance costs for the vegetation once it is established as it holds the banks naturally, as compared to concrete improvements that constantly need repairs.[103]

Check dams. Check dams are small structures constructed in gullies or other small watercourse and may be made of concrete masonry, rock, rock and earth, straw bales, sandbags, wire fence, or other materials. Erosion is reduced or prevented by reducing runoff velocities, promoting deposition of sediment, and stabilization of channel grades.[104] Check dams may be used to prevent gully erosion (usually during the construction period) either in temporary channels or in permanent channels which are unvegetated and, therefore, temporarily unable to handle design flows. In some cases, if carefully located and designed, these checks can remain as permanent installations with very minor regrading, etc. They may be left either as spillways, in which case accumulated sediment would be graded and seeded, or as checkdams to precipitate further sediment coming off that site, in which case a clean-out would be required. Because of their temporary nature, many of these measures are visually poor and it is essential to remove them before dwelling units are let or sold. Removal of these measures may constitute a significant cost and temporary checkdams are suitable for a limited drainage area only.[105]

Weir. A weir is a small dam set in a stream to raise the water level or divert its flow. A weir may be employed to control sedimentation in large streams. Weirs cause minimal turbidity,[106] reduce channel grade and dissipate the energy of the flowing water.

Bank stabilization was defined as follows in the Baltimore City Erosion and Sediment Control Manual, Ordinance 1013: "The control of bank erosion in main stream channels can be accomplished in various ways. Methods commonly used include sod, concrete, riprap, rock cribs, groins, jetties, fencing, piling, gabions, etc. The purpose of bank control measures is to install a barrier that will withstand the erosive forces, exerted by flowing water or create a bank roughness that will reduce the erosive power by dissipating the energy of the water as it moves along the bank line."[107] The New Castle County (Delaware) Surface and Ground-Water Drainage Code (Ordinance No. 69-71) requires on-site stabilization of watercourses affected by runoff increases and also requires of each person or corporation making surface changes to "pay his proportionate share of the total cost of off-site improvements to the common natural watercourse except those required to existing state roads, based on a fully developed drainage area."[108]

Figure 3.5 illustrates several stream bank stabilization measures.

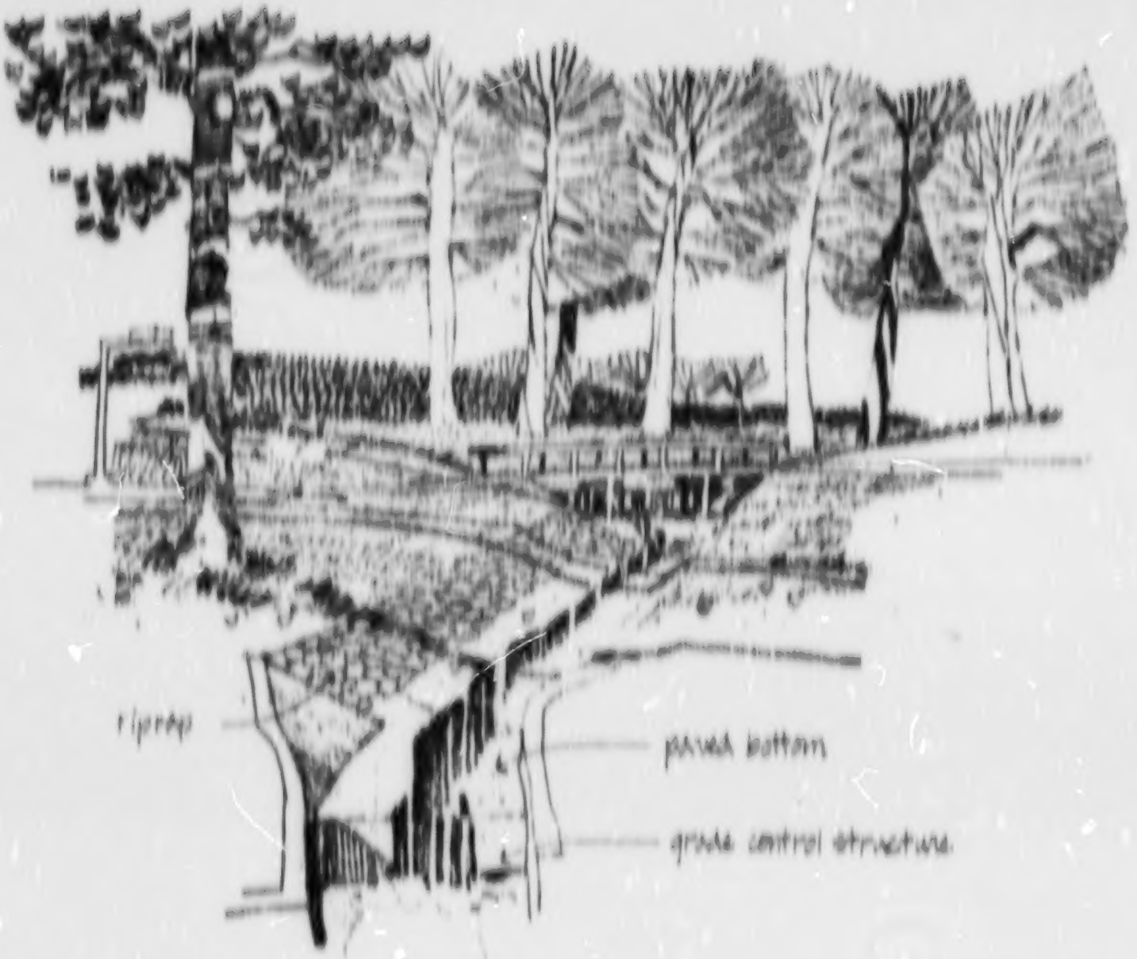

riprap
paved bottom
grade control structure

Figure 3.5: Control Measures Are Often Used in Combination

3.3.5 Design and Stabilization of Surface Drainageways

Surface runoff and runoff intercepted by erosion control measures such as diversions must be collected by drainageways and let out in stabilized areas, storm sewers, or sediment basins. The design of these drainageways insures that runoff is transported without risk of erosion or flooding. Unless surface drainageways are adequately designed, constructed, and maintained, they can become a major source of sediment pollution.

Development should be planned to maintain and utilize the naturally stabilized drainageways that exist on a site. Increases in runoff volume and velocity because of changes in soil and surface conditions during and after construction must be anticipated. Where the capacity of the natural site drainage channels is exceeded, additional capacity, stabilizing vegetation, and/or structural measures may be needed.

Allowable design velocities vary with soil conditions, the character of the channel lining (either bare, vegetative, or structural), and anticipated runoff volume. Formulas and techniques for determining the runoff flows, channel cross sections, slopes, stabilizing covers, and design velocity may be obtained from Soil Conservation Service offices.[109]

This subsection presents a number of measures involved in the design and stabilization of surface drainageways: bare channels, grassed waterways, lined channels, grade control structures, sediment traps, and sediment basins. Some of these measures may be temporary only, while others may become part of the permanent drainage system.

Sediment Trap. The first essetnial step in preventing sediment from entering streams and waterways is to control erosion on construction sites. A second necessary step in sediment control is to trap sediment that is transported by runoff before it reaches streams and waterways or leaves the construction site. To trap sediment, the runoff must be detained for a sufficient period of time to allow the suspended soil particles to settle out. The amount of sediment which is deposited will depend on the speed at which runoff flows through the sediment trap, the length of time that runoff is detained, and the size and weight of the soil particles which are in suspension.[110]

Sandbags, straw bale barriers, and excavated sediment traps, placed at regular intervals within a drainage channel, are temporary sediment control measures which are easy and economical to construct. Sandbag barrier sediment traps are constructed of bags filled with sand or crushed rock and stacked in an interlocking manner which is designed to trap sediment and reduce the flow velocity. Straw bale barrier sediment traps are constructed of bales of hay or straw stacked or staked in place. Tying the bales to stakes with wire provides additional stability.[111]

Sandbag and straw bale barriers may also be used at storm drain inlets and along property lines, preventing sediment from entering a partially completed storm sewer system, and reducing sediment deposition on neighboring properties.

Sediment Basin. Streams may also be protected from increased sediment loads by trapping runoff in sediment basins before it is released into stream channels. In addition to trapping sediment, these basins are designed to release runoff at non-erosive rates. Such sediment basins may be constructed by excavating a pit or by construction of an impoundment. Sediment basins often consist of an earthen dam, mechanical spillway (including a perforated riser pipe) and an emergency spillway. The construction of sediment basins should be completed before clearing and grading begin. They are generally located at or near the low point of the sites. Points of discharge from sediment basins must be stabilized. Permanent sediment basins may become part of the final development in the form of ponds or small lakes, which can be quite attractive after the development is completed.[112]

Construction of a sediment basin will benefit the developer by avoiding a number of problems: downstream riparian properties will not be damaged by sediment deposits originating from the development; sediment deposits downstream will not reduce the capacity of the stream channel; sediments will not cause the clogging of downstream impoundments and other facilities; and sediments will not reduce the light reaching the streambed, which might in turn reduce available oxygen. It should be noted, however, that only particles larger than 10 microns will be settled out by gravity. The efficiency of the basin in settling smaller particles is much less than that for larger particles, such as sand on silt. Therefore, much of the clay particles will probably not settle in the basin.

Bare Channels. The least expensive form of drainageway, bare channels, should be used with caution and only in areas where the channel gradient is low. Bare channels should not be used in soils which have moderate to high erosion potential.[113]

Grassed Waterways. Runoff can be handled by grass channels for velocities up to 8 fps., if correctly graded and stabilized. A grassed waterway is a much more stable form of drainageway than a bare channel and should be used where a bare channel would be eroded. The grass tends to slow the runoff and filter out sediment. On steep slopes the use of grass channels will be constrained by the difficulty of keeping within the limits of hydraulic gradient prescribed; in the case of highly erodible soils a lower design velocity must be used. Natural channels may often be improved by regrading and grassing.

Grassed waterways are less expensive than those lined with concrete or stabilized by "bio-technical" methods and are much more visually acceptable than those lined with concrete. The vegetated waterway also encourages infiltration, further reducing the runoff problem. Careful design and maintenance of grassed waterways is required if gully erosion is to be avoided. The capacity of the drainageway must allow for construction of additional impermeable areas in the area served by the channel.[114]

Lined Channels. Structural linings are necessary in drainageways where vegetation cannot be established because flow is of long duration in the channel, runoff velocities are high, erodible soils exist, or slopes are very steep. The most commonly used channel linings are concrete, asphalt paving, or riprap. Information on how to design and construct lined channels may be obtained from the Soil Conservation Service. In general, vegetative stabilization and the use of permeable channel linings, such as non-grouted riprap, are preferred to the use of impermeable linings like concrete.[115] Concrete lined channels are visually unattractive and do not permit infiltration of runoff.

Grade Control Structures. Grade control structures may be employed to reduce the velocity of runoff in drainageways. These measures may be either temporary or permanent, and include drop spillways, pipe drops, and pipe spillways. A drop spillway slows the velocity of the runoff, reducing its erosive power. A pipe drop removes sediment and turbidity, and may be designed to handle large volumes of flow. A pipe spillway removes sediment and turbidity, and may be incorporated as part of the permanent drainage system.[116] Grade control structures counteract gully erosion in waterways by reducing the gradient of the channel. They should be used when physical conditions are too severe for the satisfactory establishment of vegetation cover, being clearly preferable over an impermeable lining. To prevent undercutting at the toe, all structures should extend several feet or more below the existing ground surface. The selected design capacity should be for a storm of a greater frequency than the one used for the drainage channel because of the damage that could be done to the structure if it were to overtop.[117] Grade control structures concentrate the volume of water flow and increase its velocity at the structure, and, therefore, banks around grade control structures often require additional stabilization measures.[118]

3.3.6 Other Erosion and Sedimentation Control Measures

This subsection describes a number of erosion and sedimentation control measures which may be employed to protect enclosed drainage systems, large flat surface areas, and adjacent properties. The following measures are considered: filter inlet, aggregate cover, curb and gutter, windbreak, filter berm, and traffic.

Filter Inlet. The capacity of the storm sewer system itself can be severely impaired by sediment deposits within the system. Sediment should be prevented from entering the enclosed storm sewer by the use of small, temporary sediment traps and filters at system inlets. Filters made of crushed rock, sod, or straw bales can be placed at inlets where sediment traps cannot be constructed. It is essential to regularly check and clean out these sediment traps and filters to insure that they function properly.[119] A sod filter is inexpensive and easy to construct and provides immediate protection. A straw bale filter can be located as necessary to collect sediment and may be used in conjunction with a snow fence for the site.[120]

Aggregate Cover. Areas being prepared for paving should be protected by the use of aggregate cover. Aggregate cover stabilizes the soil surface while allowing the movement of construction equipment on the right-of-way. The aggregate cover may also be used as part of the permanent base in the construction of paved areas.[121]

Curb and Gutter. Concentrated runoff leaving paved areas is highly erosive. After construction is complete, the paved roadway itself can serve as a drainageway with curbs and gutters conducting runoff to enclosed drainage system inlets. Where it is not economically feasible to install curbs and gutters, paved surfaces should be designed so that runoff will travel the shortest possible distance across the paved areas. This will prevent large accumulations of runoff from leaving paved areas at high velocities in any one area.[112]

Windbreak. A windbreak, such as a snow fence, may be employed to minimize wind erosion on large flat surface areas. Neighboring properties may also be protected.[123]

Filter Berm. A filter berm is a temporary ridge of gravel or crushed rock constructed across a graded right-of-way to retain runoff while at the same time allowing construction traffic to proceed along the right-of-way. They are used primarily across graded rights-of-way that are subject to vehicular traffic, but are also applicable for use in drainage ditches prior to roadway paving and establishment of permanent ground cover.[124] Filter berms intercept and divert runoff to stabilized areas or prepared drainageways, and serve to slow runoff and collect sediment.[125]

Traffic Control on Construction Roads. Being in constant use, construction roads may be a particular source of pollution. Where feasible, alternative routes should be made for construction traffic: one for use in dry conditions, the other for use in wet conditions employing a number of control measures. Where possible, the construction road should be routed along the same line as permanent roads so that the permanent roadbed may be used for construction traffic. Efficient construction road stabilization not only reduces on-site erosion, but can significantly speed on-site work, avoid instances of immobilized machinery and delivery vehicles, and generally improve working conditions under adverse weather. Mud on vehicle tires is significantly reduced, avoiding a hazard by depositing mud on the public roadway by dump trucks, delivery vehicles, etc. Inlets and other partially completed storm drainage structures are protected during construction. However, measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area. Therefore, in addition to such measures as aggregate cover, filter inlets, filter berms, etc., it may be desirable to employ alternative routes for construction traffic. Each route can be rested alternatively and critical areas stabilized. In some cases it may be desirable to have a good weather route and a wet weather route.[126]

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4.0 REGULATORY APPROACHES

The technical approaches discussed in Chapter 3 above can be implemented through the regulatory, fiscal, and proprietary powers of state and local government. Despite the now dominant role of the Federal government in regulating point sources, the control of nonpoint sources--especially stormwater runoff and leachate from septic tanks and landfills--remains almost entirely a state and local responsibility. This distinction is clearly recognized in Section 208 of the Federal Water Pollution Control Act Amendments of 1972, under which areawide strategies, including regulatory programs, are to be developed for controlling all sources of water pollution. Section 208 contemplates, moreover, a planning approach that proceeds from the bottom up, with important initiatives to be taken by local governments, both separately and in cooperation with one another. This approach recognizes that preventive strategies for managing nonpoint sources are inseparable from land use controls, which have traditionally been exercised for the most part by local governments.

The aim of the present chapter is to indicate ways in which state and local governments can exercise their powers for the purpose of regulating nonpoint sources, especially stormwater runoff. Eight specific regulatory approaches are discussed:

(1) Purchase of interest in lands to be preserved as open spaces or for non-intensive uses that will not interfere with the land's natural capacity to absorb and to purify stormwater or other effluents. This section covers a broad range of techniques, not all purely "regulatory." (4.2.1)

(2) Capital-investment programming for extension of sewerage and other public services to such locations and at such rates over time as will serve to channel development into suitable areas, to discourage it in areas where it is likely to have adverse effects upon water quality, and to accommodate at all times whatever wasteflows it generates. (4.2.2)

(3) Designating sensitive, water-related lands on which development will be restricted or made subject to conditions for the purpose of protecting water quality. (4.2.3)

(4) Conditioning development permission upon environmental impact assessments that assure minimization of water quality problems incident to development. (4.2.4)

(5) Requiring that development proceed along lines and in ways that preserve natural processes associated with the hydrological cycle. (4.2.5)

(6) Conditioning development permission upon compliance with technical standards for controlling runoff, erosion, and sedimentation. (4.2.6)

(7) Controls over land disposal of wastes for the purpose of protecting water quality, including controls over solid waste disposal and use of septic tanks. (4.2.7)

(8) Regulatory and administrative controls over inplace or accumulated sources. (4.2.8)

Since a great deal has already been written in this field, the reader will be referred at various points to selected portions of the literature. Our concern here cannot be to exhaust the subject, but only to survey, with the aid of examples of actual practices from around the country, the range of regulatory approaches that are open to state and local governments. Before adopting any of them, it is strongly recommended that the decision-maker refer to the relevant bibliography and consult legal counsel on the particular laws of his state as construed by its courts. The variations in legal authorities among the fifty states are numerous; the reader is therefore cautioned not to assume that a solution adopted by one locality can be readily transferred to any other. On the other hand, the range of possible regulatory approaches is finite, and one or more of those described below may be found suitable, with appropriate modifications, to the needs of many localities.

Several other caveats should be stated at the outset concerning the use of the materials that follow.

Regulatory power is rarely exercised for the exclusive purpose of protecting water quality from nonpoint sources of pollution. Additional purposes are almost always present, in the pursuit of multi-faceted environmental, economic, and social objectives. This is true even with respect to regulations that are specifically addressed to the control of runoff, erosion, and sedimentation. In addition to preserving water quality, such regulations may aim to avoid flood damage, preserve land and ecosystems, protect esthetic and other amenities, recharge groundwater supplies, and channel development along suitable lines. In choosing among strategies for nonpoint source control, then, the decision-maker will inevitably find himself taking into account a host of considerations that include but go well beyond water quality. He may try to work from a singular point of view, but piecemeal regulation without overall planning can perpetuate or aggravate conflict among different social objectives. It is therefore recommended that nonpoint source controls be integrated to the maximum possible extent with comprehensive planning for land use and development in all affected areas. (Refer to Chapter 2.)

For convenience, each of the regulatory approaches is presented under a separate heading. It should be emphasized, however, that these approaches are not mutually exclusive; each has its own distinguishing features, but they also overlap one another. In fact, the best results are likely to be achieved by some combination of two or more approaches. For example, the districting of sensitive areas (such as wetlands or hillsides) on which development is to be restricted could be combined with a capital improvement program that positively channels development into more suitable areas. Ordinances prescribing control of erosion and sedimentation can operate in buffer zones surrounding conservation districts, and purchases of conservation easement or systems of transferable development rights can alleviate inequities caused by restrictions on development. Natural performance standards with respect to particular types or gradients of soils can facilitate preparation of environmental impact statements whenever these are prescribed as conditions for securing approval for development. Such examples could be multiplied indefinitely; the decision-maker must consider what combination of control strategies best suits the needs of his locality.

Preceding the discussion of the specific regulatory approaches will be a brief description of the sources of state and municipal regulatory authority over nonpoint sources such as stormwater runoff. A final section will raise several issues related to implementation of these approaches.

4.1 The Legal Framework and the Scope of Legal Authority

The powers reserved to the states under the Tenth Amendment to the United States Constitution include the powers to tax and spend for the public welfare and for the maintenance of government itself; to acquire, manage, and dispose of property for public purposes; and to regulate private activity in the interest of the public health safety and general welfare. These sovereign powers of the states, particularly the regulatory ones, are generally known as "police powers." They are the ultimate source of authority for all the regulatory approaches discussed in this chapter. Their exercise is limited by a number of constitutional restraints, of which the most important for our purposes are that the governmental power be exercised in the public interest; that the means of government intervention be reasonably necessary for the accomplishment of a public purpose; that standards of procedural due process be observed in the regulation of private activity; that a state refrain from discriminating unreasonably against any class of persons in the application of its laws; and that private property not be taken for public use without just compensation. Within these constitutional limitations[1], the states may avail themselves of a broad range of strategies for environmental protection.

Any or all of the approaches mentioned previously could be undertaken entirely at the state level, through enactments of the state legislature and administration of regulatory, fiscal or proprietary functions by agencies of the executive branch to which the legislature has delegated the necessary authority. However, the states have delegated a large measure of their police powers to local governments, either through "home rule" provisions of state law, or, more commonly, through enabling statutes. State constitutions, municipal charters adopted in accordance with constitutional or statutory provisions, and enabling legislation are the fundamental sources of local government authority. It must be borne in mind that local governments have no inherent authority of their own, but only such powers as are granted to them by the constitution and statutes of the state in which they are located. Thus, there may be a threshhold question as to whether a local government has the authority to legislate in a particular manner to deal with a particular problem. For example, it may lie within the general police power of a municipality to regulate the disposal of waste, but not to impose a tax upon waste products released to the environment, even though the legislative goal might be the same in either case. In such an event, the municipality would have to obtain specific legislative authority to impose a tax.

Home rule provisions, which are designed to carve out a legislative jurisdiction in which local governments can operate free of state interference, typically authorize municipalities "to exercise all powers of local self-government and to adopt and enforce within their limits such local police, sanitary and other similar regulations, as are not in conflict with general laws."[2] Such a clause may, for example, authorize a municipality to require of a subdivider that he dedicate land for public purposes, even in the absence of any statutory authority to exact such a condition. On the other hand, municipalities in home rule jurisdictions may not in fact have greater powers to control pollution than in states where home rule is not recognized. This is true for two reasons. First, state law may "preempt the field" in matters transcending local concern. State regulation, in other words, may be so pervasive or so comprehensive with respect to a particular activity that no room is left for local governments to adopt regulations of their own pertaining to the same subject matter. It is a question of legislative intent, commonly interpreted by the courts, as to whether state intervention is preemptive or whether state and local enactments can work concurrently in the same field. Where preemption does not exist, local regulations are commonly sustained if they require controls as strict as or stricter than state law. If conflict is otherwise found to exist between state and local enactments, the former will always prevail. These determinations are quite independent of the question whether home rule has been granted municipalities in matters of local concern.

Secondly, state enactments delegating police power to local governments may be so broad in scope as to approach constitutional home rule by legislative means. For example, municipalities may be authorized by statute to "take all action necessary or convenient for the government of their local affairs," or to "enact all ordinances, regulations, and by-laws for the well-ordering, managing, and directing of the prudential affairs and police of their respective towns."[3] Thus, state legislatures may delegate broad powers to municipalities to provide for the safety, health, welfare, and convenience of their respective communities. So even in jurisdictions without constitutional home rule, municipalities may have extensive powers to regulate pollutant-generating activity.

The upshot of this brief discussion of a very complicated topic is that local governments may have greater powers than they realize, but should obtain the advice of legal counsel on the extent to which the absence of home rule, restricted statutory authorization, state preemption, or judicial precedent may limit local power, before attempting to extend the reach of their environmental controls.

In most states, enabling legislation authorizes local government to adopt zoning ordinances, subdivision regulations, and building and health codes. These traditional regulatory vehicles can be used to a greater extent than is generally appreciated for purposes of controlling nonpoint sources of pollution. Specific authority to regulate waste disposal, land-disturbing activities, and stormwater runoff may also be delegated by enabling laws. The first step of the 208 planner is to determine what can be done with the laws already on the books.

Zoning enabling acts commonly provide, in part, that local governments may regulate

> the percentage of a lot that may be occupied, the size of yards, courts, and other open spaces, the density of population, and the location and use of buildings, structures, and land for trade, industry, residence or other purposes.... Such regulations shall be made ... to secure safety ... to promote health and the general welfare ... to prevent the overcrowding of land, to avoid undue concentration of population, [and] to facilitate adequate provision of ... sewerage and other public requirements. Such regulations shall be made with reasonable consideration ... to the character of the district and its peculiar suitability for particular uses, and with a view to conserving the value of buildings and encouraging the most appropriate use of land throughout such municipality.[4]

Pursuant to provisions such as these, a municipality may require minimum lot sizes in areas where the capacity of soils to absorb septic tank waste is limited; may designate districts in which land uses are restricted because of natural features of the land that would affect drainage and seepage; and may require that the pace and pattern of development be governed by the time-phased extension of sewerage and other municipal services in accordance with a capital development program.

In Steel Hill Development, Inc. v. Town of Sanbornton,[5] a federal court recently upheld a six-acre minimum lot size ordinance as a legitimate stop-gap measure, designed in part to prevent water pollution and other forms of environmental degradation, until such time as the town could plan some longer range approach for coping with the intense development pressures it was facing.[6]

Under zoning enabling acts or amendments to them, municipalities may also be authorized to permit cluster zoning and planned unit development, which afford flexibility to a developer in designing his site so long as he meets overall density restrictions and provides certain services or amenitites. In this manner, development may occur in "clusters or more environmentally tolerant parts of a site while sensitive areas are retained as open space.[7]" In Bucks County, Pennsylvania, it has been proposed to stipulate through a zoning ordinance not only density requirements but also permissible ratios of open spaces to impervious surfaces.[8] To avoid erosion and consequent water pollution as a result of further development, the city of Palo Alto, California, recently adopted an open space zone in which one-family dwellings were the most intensive use that would be permitted.[9] The zoning ordinance of Harristown, Illinois, contemplates the establishment of conservation zones, whose purpose is:

> to prevent the construction upon or alterations of ... natural environments which have natural conditions of soil, slope, susceptibility to flooding or erosion, geological conditions, vegetation, or interaction between the aforesaid which makes such lands unsuitable for urban development. Further, this zone is established to protect areas of the environment, that, if altered, would cause health or population problems, and environmental degradation.[10]

In the celebrated case of *Golden* v. *Planning Board of Ramapo*[11] the Court of Appeals of New York held that population growth could be controlled through restrictions on the sequencing and timing of development, even though the relevant zoning law did not expressly authorize such control.

The foregoing examples illustrate the potential reach of the zoning authority in preserving open spaces for retention and infiltration of rain water, and for guarding against premature or unsuitably located development that could cause nonpoint pollution. It will be necessary to assure in all cases, however, that land use restrictions do not go so far as to constitute a compensable taking of private property.[12]

Under planning enabling acts, localities are commonly authorized to adopt subdivision regulations, to which a developer must conform before he can obtain approval of his plat. In some jurisdictions, courts have held that local governments may impose conditions requiring a subdivider to dedicate land for public open space before he can obtain approval.[13] Platting may be prohibited or severely restricted on critical water-related lands, such as floodplains, wetlands, shorelands, and steep slopes, where intensive development could be expected to jeopardize water quality. Subdivision approval is also a fitting juncture at which to require submission of environmental impact statements detailing aspects of the site plan (including erosion and sedimentation controls) that are designed to minimize adverse effects on the environment, and other evidence that the subdivider has arrayed the components of his plan in harmony with the natural features of the site.[14]

Building and sanitary codes typically authorize local governments to "enact and enforce ordinances regulating the construction ... maintenance, sanitation ... inspection ... and control of ... buildings, dwellings, and structures of all types and descriptions, whether used for human habitation or otherwise ...."[15] Accordingly, construction codes may require use of stormwater detention facilities or of permeable materials to increase infiltration, and sanitary codes may regulate the location and construction of septic tanks and landfills, in part by reference to the permeability of the soil and the level of the water table. Moreover, both types of code can and should impose ongoing responsibilities on owners or operators of control facilities to maintain them in good repair. For example, the code may make it the duty of landowners to prevent accumulations of sediment behind detention devices (as a precaution against sediment runoff) and to have their septic tanks periodically cleaned out by licensed scavengers. A good code will also provide for periodic inspection by officials to monitor compliance.

Imaginative exercise of the foregoing traditional sources of authority can go far toward controlling nonpoint sources of pollution at the local level. We turn next to taking a closer look at the principal varieties of control strategies that are in use today in one or another part of the country.

4.2 Specific Regulatory Approaches and Techniques

4.2.1 Acquisitions of Land for Open Space and Other Non-Intensive Uses

As noted in earlier chapters, particular parcels of land may play a critically important role in the hydrological cycle by virtue of their capacity to retain or absorb stormwater, or because incompatible developments upon them might cause an especially serious problem of runoff, erosion, and sedimentation. The best and most direct way of securing the protective functions of such lands is to acquire them for public purposes, including conservation or recreation, for which extensive grading, stripping, and paving will not be required.

Grants to defray the cost of purchasing recreational properties may be available from the Land and Water Conservation Fund administered by the U.S. Department of Interior's Bureau of Outdoor Recreation, under 16 USC § 460l, and from parallel state programs. Even so, public land acquisition is likely to be an expensive proposition for a community. There is not enough federal and state money to go around for this purpose and the community will ordinarily have to pay for some part of the purchase cost.

Conservation easements or restrictions, which can be acquired either by gift or purchase, are a less costly technique for avoiding environmentally degrading developments. A New Jersey law, for example, authorizes certain governmental bodies to acquire "interests or rights consisting, in whole or in part, of restrictions on the use of land by others."[16] A Pennsylvania law enables counties to covenant with landowners for the preservation of land in farm, forest, water supply, or other open space uses.[17] By such a covenant, the land owner commits himself to maintaining his land as open space for 10 years and the county promises in turn to assess the property at a value no greater than it is worth with the encumbrance of the restrictive covenant. This device gives the owner some relief from property and estate taxes as well as a charitable deduction from his income tax. It also enables him to retain title and to continue living on the land without intrusions from the public or to use the land in any manner he wishes so long as he preserves it consistently with the terms of the restriction. In effect, the owner sells (or donates) and a local government agency or charitable corporation buys only certain development rights in the property, at what may be a considerable savings in costs compared to the price that would have to be paid for purchasing the entire title. Federal and state assistance, moreover, may be available for such partial acquisitions.

The Massachusetts Conservation Restriction Law[18] is an example worth discussing in some detail. It defines conservation restrictions as rights appropriate to keeping "land or water areas predominantly in their natural, scenic or open condition or in agricultural, farming or forest use." Activities that could jeopardize water quality may be expressly forbidden or limited by such restrictions, including: "(a) construction or placing of buildings ... or other structures on or above the ground, (b) dumping or placing of soil or other substance or material as landfill, or dumping or placing of trash, waste or unsightly or offensive materials, (c) removal or destruction of trees, shrubs or other vegetation, (d) excavation, dredging, or removal of loam, peat, gravel, soil, rock, or other mineral substance ... (3) surface use except for agricultural, farming, forest or outdoor recreational purposes or purposes permitting the land or water area to remain predominantly in its natural condition, (f) activities detrimental to drainage, flood control, water conservation, erosion control or soil conservation...." The restrictions can be tailored to fit the particular situation. Generally, they provide that all rights not expressly conveyed are reserved to the grantor, thus allowing a range of consistent uses. Occasionally, an easement allowing the grantee to enter on the premises and inspect for violations is conveyed along with the restriction.

The acquiring party must be either a governmental or a charitable body whose purposes include conservation. Acquisitions may be by eminent domain, gift, or contractual agreement, and must be approved by the appropriate state and local agencies. When a restriction has been recorded so as to provide public notice that the land is encumbered, it becomes enforceable over time from one landowner to another, by means of an injunction or proceeding in equity if necessary.[19] The landowner may be released from the restriction upon payment of such consideration as the holder may determine, but only after a public hearing on the matter following upon advance public notice. "The requirement that a public hearing be held before any action is taken will safeguard against the use of variance practices that have proved so dangerous and arbitrary in the administration of the zoning power."[20]

Valuing conservation restrictions for tax purposes may pose some problems,[21] but these can be surmounted. It is also advisable to provide for roll-back taxes, conveyance fees, or penalty provisions in the event that a restriction is discontinued or violated, in order to discourage abuse of this device by land speculators. As for whether the cost of a conservation restriction in terms of lost property tax revenues will be more than offset by the benefit of open-space preservation to the community, that is a question that can only be answered by reference to the community's overall land-use policies. In this connection, it should be pointed out that development of certain lands may saddle a community with higher costs for new services than it will receive in new tax revenues, and that preservation of open spaces may well have the effect of increasing the assessable values of surrounding tracts.

Perhaps the principal advantage of the conservation restriction is that it is a non-adversarial technique for preserving open spaces, without the necessity of having to purchase them outright or to regulate them to the point where takings might be deemed to have occurred.

4.2.2 Time Phased Capital Investment and Development Guidance

By guiding the location, sequence, and timing of new municipal facilities, including sewerage and drainage, a community can discourage premature development that might cause nonpoint pollution in the absence of such facilities and can channel development positively into areas where, because of favorable topographical conditions, it is least likely to generate polluted runoff or leachate. Development guidance through the time-phased provision of municipal services can therefore serve indirectly to prevent sources of nonpoint pollution from arising, while promoting a wide range of environmental and economic objectives.

A controlled growth plan of this sort in the town of Ramapo, New York was upheld in the celebrated case of *Golden* v. *Planning Board of Ramapo*.[22] The Town of Ramapo had amended its zoning ordinance to require special development permits, which would be granted in each case only if the land to be developed was located in an area served by a minimum level of certain community facilities. These facilities, including sewerage and drainage, were to be installed in accordance with a master plan, an official map, and an 18-year capital improvement program to which the town had committed itself. Development permits could be granted only on the basis of a "point system" that reflected the proximity of the site to such improvements, but a developer could acquire additional points and thereby accelerate his eligibility by providing the necessary improvements himself. Lands whose development potential was deferred under this scheme could be afforded reductions in property taxes. The announced purposes of the program as a whole were to afford relief to the citizenry from the rising burden of the total tax load and to eliminate unplanned and uncoordinated growth which outstripped the capacity or availability of supporting community services such as drainage, roads, and sewers.

Faced with this carefully conceived strategy, the New York Court of Appeals upheld the Ramapo ordinance as applied to plaintiff landowners, who had attacked it on the grounds that its timing controls were not authorized by the state's Zoning Enabling Act, that it was exclusionary in intent, and that it constituted a public taking of their properties without fair compensation. While conceding that the relevant statutory provisions did not specifically authorize controls over the sequence and timing of development, the court held that the authority delegated by the Zoning

Enabling Act to avoid 'undue concentration of population" and to "facilitate adequate provision of public services" included time-phased controls as "a necessary concomitant to the municipality's recognized authority to determine the lines upon which local development shall proceed...."

To the objection that the ordinance was exclusionary, the court pointed out that the town was committed to expanding its facilities in an orderly manner and to ensuring "continuous development commensurate with the town's obligation to provide such facilities. They seek, not to freeze population at present levels, but to maximize growth by the efficient use of land...." Finally, the court held that the ordinance did not amount to a public taking, since deferrals of development rights under the ordinance were only temporary and property owners could elect to accelerate the rate of development by installing at their own expense the necessary public services to bring their parcels within the required number of development points. Moreover, even during the period of deferred development rights, landowners were not deprived of all reasonable uses of their property; they could, for example, construct single family residences without reference to the restrictive provisions of the ordinance. "In sum, where it is clear that the existing physical and financial resources of the community are inadequate to furnish the essential services and facilities which a substantial increase in population requires, there is a rational basis for 'phased growth' and hence, the challenged ordinance is not violative of the Federal and State Constitutions."

A somewhat similar approach was upheld by a federal court in *Construction Industry Association of Sonoma County v. City of Petaluma*.[23] Petaluma had adopted a 500 per year limit on the number of new dwelling units that could be constructed in the city, pursuant to an announced policy of preserving its small-town character and surrounding open space, of keeping new development within the bounds of available municipal services, and of providing a permanent green belt around the city. The court held that the "public welfare" purpose of zoning was sufficiently broad to include these objectives. The Petaluma plan was therefore deemed "a reasonable and legitimate exercise of the police power." In so holding, the court observed that the plan did not freeze local population at present or near-present levels and did not have the undesirable effect of walling out any particular income class or racial minority group. In fact, the plan contemplated that between 8 and 12 per cent of each year's housing quota would be allocated to low or moderate income housing.

These cases teach that a municipality, through careful exercise of its powers to plan for land use and to program for investment, may regulate the pace and pattern of its own development in accordance with environmental objectives. These may include avoidance of water pollution from nonpoint sources, at least until such time as municipal facilities are available to collect and treat waterborne wastes. However, the Ramapo and Petaluma approaches cannot be employed unless the municipality is prepared to establish land-use policies and programs ranging far beyond control of water quality. Moreover, unless the approach is carefully conceived, it will run a high risk of being invalidated on constitutional grounds.[24]

4.2.3 Restrictions on Development Affecting Critical Natural Resources

This approach begins with the recognition that development should be substantially restricted on certain types of land that play an important part in protecting or -- if improperly developed -- in degrading the quality of ground and surface waters. Included in this category are shorelands surrounding streams and lakes, aquifers and their recharge zones, wetlands, woodlands, and hillsides. Soils that are wet because of high water tables or that are particularly vulnerable to erosion might also be included.

A municipality may wish to designate special districts containing such sensitive natural features as overlays to general zoning districts, and to subject land use in the overlay districts to supplemental restrictions. These will be designed, in part, to minimize interference with the natural capacity of the land to retain, absorb, and purify wet weather flows (stormwater) or dry weather flows (principally leachate from septic tanks and landfills). For example, septic tanks might be prohibited in wet or permeable soil districts; minimum percentages of vegetative cover might have to be preserved on hillsides in order to prevent erosion; and filling of wetlands might be prohibited or sharply restricted in order to protect their functions of purifying the effluents they absorb and of recharging surface waters in times of low flow. For each special district, a list of permitted uses, prohibited acts, and procedures for securing approval of special or conditional uses may be set forth, all geared to protecting critical natural resources against incompatible development.

Regulations applicable to land-use in special districts may be of several kinds. The zoning ordinance of Harristown, Illinois, provides for conservation zones in which uses are sharply restricted:

> "The Conservation Zone is established to prevent the construction upon or alteration of rural or natural environments which have natural conditions of soil, slope, susceptibility to flooding or erosion, geological condition, vegetation or an interreaction between the aforesaid, which makes such lands unsuitable for urban development. Further, this Zone is established to protect areas of the environment, that, if altered, would cause health, or pollution problems and environmental deterioration. The Conservation Zone will also ensure adequate areas for future conservation and recreation pursuits."[25]

With respect to permitted uses, land-use regulations for special districts (or for any other property) may specify site requirements, construction techniques, and protective maintenance measures (e.g., porous surface cover, no septic tanks close to water tables, periodic removal of accumulated sediments).[26] Alternatively, the regulations may prescribe natural performance standards, such as rates of runoff or soil loss through erosion that are no greater than would have occurred if the land had been permitted to remain in an undeveloped state.[27] This approach could leave the developer free to make whatever use of his land and to install upon it whatever nonpoint source controls he may wish, so long as the land in its developed state achieves the required standards for performance.

Wisconsin law treats shorelands as a special management unit in order to minimize pollution from runoff and septic tanks associated with shoreland developments.[28] The law authorizes counties to enact separate zoning ordinances, including protective regulations, for all incorporated lands within 1,000 feet of a lake and 300 feet of a navigable stream.[29] These ordinances must meet minimum standards for shoreland protection promulgated by the State Department of Natural Resources. Accordingly, the Department adopted a set of regulations and a Model Shoreland Protection Ordinance for the further guidance of the counties. The Ordinance, which has in fact been widely adopted, specifically regulates the location and construction of septic tanks and soil absorption fields; specifies minimum set backs for various facilities; limits tree-cutting to a 35-foot strip paralleling the shoreline and clear-cutting to 30 per cent of a strip; requires preservation of shrubbery "as far as practicable," and, where removed, its replacement with other vegetation that will be "equally effective in retarding runoff, preventing erosion and preserving natural beauty;" and prohibits filling, grading, lagooning, or dredging that would result in substantial detriment to navigable waters by reason of erosion, sedimentation, or impairment of aquatic life.

Two restrictive classes of shoreland zoning districts are established under the Ordinance. The conservancy district is designed primarily to protect shorelands designated as swamps or marshes, which are described as "seldom suitable for building." Conservation and recreational uses are practically the only ones permitted in such a district, except that certain uses (dams, farming, piers, and docks) may be allowed upon obtaining a special exception permit. In residential/recreational districts, single-family dwellings are also permitted, and, by means of special exception permits, commercial and tourist facilities.

The Ordinance also prohibits the subdividing of shoreland which the county planning agency deems unsuitable for that purpose "for reason of flooding, inadequate drainage, soil and rock formations with severe limitations for development, severe erosion potential, unfavorable topography, inadequate water supply or sewage disposal capabilities, or any other feature likely to be harmful to the health, safety or welfare of future residents of the proposed subdivision or of the community." For subdivisions not served by public sewers, the ordinance correlates minimum lot areas with soil, ground water, and slope characteristics.

The Wisconsin program is a clear example of how the natural resource functions of critical land and water areas can be protected by special zoning for particular uses and by site plan requirements designed to minimize water pollution and other forms of environmental degradation.

It is possible to regulate development in critical areas without specifying in detail the standards to be met or the control techniques to be adopted. For example, the Flood Plain and Wetlands Protection Ordinance prepared for townships within the County of Oakland, Michigan, provides that conditional use permits to deposit material in or remove it from designated watercourse or wetland areas may be issued by the Township Board upon "such conditions on the manner and extent of the proposed operation, use or activity as are necessary to ensure that the intent of this ordinance is carried out."[30] That intent is quite generally stated as, in part, "to provide for the protection, preservation, proper maintenance and use of township water courses and wetlands in order to minimize disturbance to them and to prevent damage from erosion, turbidity or siltation," as well as "to provide for the protection of the township's potable fresh-water supplies from the dangers of ... pollution ...." However, in the absence of express regulatory standards, case-by-case review of land-altering proposals requires evaluative expertise. If this is not available to the reviewing agency, it may have difficulty reaching rational decisions and avoiding abuses of discretion.[31]

4.2.4 Environmental Impact Assessments

It is possible to exercise control over site design through environmental impact evaluation, even in the absence of comprehensive land use policies, plans, or programs. By amendment to a local zoning ordinance or subdivision regulation, developers can be required to submit environmental impact statements on proposed developments (beyond a certain size), as a condition for getting them approved by the local planning or zoning board. Even is such a requirement is procedural only, limited to disclosure of impacts, the exercise of assessing them and of comparing the impacts of alternative plans often has the effect of sensitizing developers to environmental values and of inducing them to propose measures for minimizing environmental harm. Further, an EIS ordinance may provide that development of certain kinds will not be permitted unless the proponent can show that it will not harm natural resources, including water quality. At the least, EIS provisions can permit case-by-case review of development proposals and furnish a point of leverage for public reviewing officials to suggest corrections in the site plan or remedial action to be taken by the developer.[32]

A subdivision regulation of the town of Lincoln, Massachusetts requires an applicant for subdivision plat approval to submit an environmental impact statement "the purpose of which is to enable the officials of the Town to determine what methods are used by the applicant to promote the environmental health of the community and to minimize adverse effects on the natural resources of the Town."[33] In preparing these statements, applicants are referred by the ordinance to a set of Environmental Quality Maps adopted by the Town and to the Soil Survey Map and Manual prepared for it by the Soil Conservation Service of the U.S. Department of Agriculture. In reviewing the statement, the Town Board will consider, among other things, "the degree to which water is recycled back into the ground [and] the maintenance and improvement of the flow and quality of surface waters." Specifically, the EIS must describe in detail the physical environment surrounding the development, and must describe and evaluate the methods to be used both during construction and on a permanent basis to control erosion and sedimentation. Further topics to be described in detail include any areas subject to flooding or ponding, proposed surface drainage systems, proposed land grading and permanent vegetative cover and methods to be used to protect existing vegetation, relationship of development to topography, any proposed alterations of shorelines or wetlands, estimated increase of peak runoff caused by altered surface conditions, methods to be used to return water to the soil, subsurface soil and water conditions, sewage disposal methods, and impact of such methods on quality of subsurface water. "Where appropriate, the Board may require soil surveys to establish the suitability of the land for the proposed storm and sanitary drainage installations." These regulations clearly impose on the developer the burden of preparing detailed plans for preventing pollution from nonpoint sources.

A subdivision ordinance of the Township of Medford, New Jersey requires preliminary plats to be accompanied by assessments of probable impacts on municipal services, including water, storm sewers, and sewage disposal, and on local lands, waters, and ecosystems.[34] Specifically, the environmental impact statement must explain the impact of the proposed subdivision on local geology, aquifers, hydrology, water tables, runoff, soils and soil loss, soil nutrient retention, vegetation, and other aspects of the local ecosystem. By reference to an Ecological Planning Study done for the town, including a series of natural resource maps, the developer is to ascertain which of the regulations identified in the study as desirable for protection of natural resources are applicable to the development he proposes. He must include those regulations in the EIS and describe the actions he will take or avoid in order to minimize adverse effects on the local environment. The regulations[35] are designed to enable land and water resources to continue functioning, by and large, as they would have done in the absence of development. Their purpose is to minimize the loss of valuable resources such as aquifers, soils, and vegetation, even as development compatible with those resources is allowed to proceed. But "[w]here there is a question as to the suitability of ... lots for their intended use due to factors such as rock formations, flood conditions, drainage or other adverse environmental impact factors, the planning Board may after adequate investigation withhold approval of such lots."

Such requirements go well beyond mere disclosure, and they suggest that environmental impact assessments can be a potent tool for protecting water quality when combined with natural resource inventories. The stronger the data base provided by a community as guidance for developers, the easier it will be for them to assess and to minimise adverse environmental impacts through prudent site planning.

Act 250 of the State of Vermont provides that no person may sell any interest in a subdivision, nor commence construction on a subdivision or development involving more than 10 acres of land, without a permit from the State Environmental Board or appropriate District Commission.[36] (The district commissioners are also agents of the State, appointed by the Governor.) Before granting such a permit, the board or commission must find that the subdivision or development will not result in "undue water or air pollution," and in making this determination, it is to consider "the nature of soils and subsoils and their ability to adequately support waste disposal; [and] the slope of the land and its effect on effluents ...." A permit will be granted if the applicant can demonstrate that his development "will meet any applicable health and water resources department regulation reduction of the quality of ... ground or surface waters flowing through or upon lands" that include steep slopes, shallow soils, watersheds, public water supplies, or aquifer recharge areas. Applicants must demonstrate that they will meet state regulations regarding the disposal of waste; that development on or adjacent to stream banks "will, whenever feasible, maintain the natural condition of the stream;" and that development along shorelines "will, insofar as possible and reasonable in light of its purpose ... retain the shoreline and the waters in their natural condition ... and ... stabilise the bank from erosion, as necessary, with vegetative cover." The Board or commission must also find that the proposed development "will not cause unreasonable soil erosion or reduction in the capacity of the land to hold water so that a dangerous or unhealthy condition may result." Note that these provisions (which illustrate the possibility of administering EIS requirements at the state level, largely through district environmental commissions) are rather general and flexible in their application.

Whether or not a proposed development will result in "undue" pollution or "unreasonable" erosion is a judgment left largely to the discretion of the administering agency. While such statutory standards have the advantage of allowing the agency to take account of the variant circumstances that different cases present, a statute like Vermont's arguably delegates too broad a discretionary power, thereby placing too great a burden on administrators to make principled, even-handed decisions from one case to the next. The risk of arbitariness should be mitigated, however, by the statutory references to the specific regulatory standards that must be met in Vermont before a development permit will be issued.

By themselves, environmental impact statements are no substitute for comprehensive land use policies. They assure neither coordination of environmental and development programs nor harmonization of the environmental effects of multiple or cumulative actions over time. "Rather it is hoped that through ad hoc project-by-project review the worst environmental problems in a single action can be minimized."[37] Ideally, the discipline of the EIS process should be combined with natural resource inventories, as in the case of the Medford Township ordinance, as well as with overall development policies and land-use standards. A combination of such techniques and controls can be an effective means of assuring that site planning incorporates measures for preventing pollution from nonpoint sources.

4.2.5 Environmental Performance Standards

"The goal of environmentally oriented land-use regulation ... is to maintain or preserve natural processes as land undergoes change for man's use."[38] When such regulations are expressed in terms of the way land actually functions -- for example, to retain or release runoff, or to lose topsoil through erosion -- they posit what could be called natural or environmental performance standards.

> "To develop this system of regulation, a community identifies the natural processes that are closely associated with public health, safety and welfare; that provide the community important benefits that are ignored through the private market mechanism. Specifically, these are processes such as runoff, erosion, and ground water infiltration which are closely linked to maintaining public water supplies, preventing hazards from floods and droughts, preserving water quality in lakes and rivers and maintaining the natural resources of the soils themselves. The community

> then establishes a specific (preferably numerical) level at which the natural process should operate, and any development of the land must be done in such a way that the natural process continues to function at this level. In contrast to a specification approach, this kind of regulation does not require designated construction techniques or site planning, but allows the developer to choose his own system of guaranteeing that natural processes continue to operate."[39]

This approach is capable of zeroing in, precisely and directly, upon natural phenomena whose disruption, distortion, or overloading causes nonpoint source pollution (as well as other forms of environmental degradation). The efficiency of the approach provides considerable freedom to the developer to use his land as he wishes and to employ whatever control measures he may choose, so long as his site plan and his construction and maintenance procedures meet the prescribed performance standards. Such standards are usually couched in terms of how the land would perform if left in a natural state, but it is possible to allow some leeway with respect to performance characteristics in order to accommodate a degree of development. In general, however, development will not meet the prescribed standards unless it is undertaken in a manner compatible with the natural environment, and this means that development proposals must reflect a sound data base and a sophisticated understanding of such disciplines as soil mechanics, geology, and hydrology as applied to the proposed site. Application of these and other related disciplines is necessary in order to measure and to minimize disturbances of natural functions.

The key to this approach is the initial step of constructing an adequate data base through a multi-faceted study of the geology, topology, hydrology, and ecosystem continuity of the community's natural resources. The essential data can be displayed in a series of maps and charts to which planners, developers, and regulators will refer. From those data, performance standards can be derived to guide the submission and review of development proposals, perhaps through procedures requiring environmental impact statements.

This approach need not be confined to particular districts of critical planning concern, but can be applied across the board to all parts of the community, including strategically important areas that may border upon water resources or upon sensitive water-related lands. The necessary factual and technical bases for employment of performance standards may be too expensive for some communities to acquire, but considerable assistance in laying the necessary groundwork can be obtained from the U.S. Geological Survey and from the Soil Conservation Service of the U.S. Department of Agriculture, as well as from the expanding body of literature on the subject.[40]

Pure performance standards, expressed entirely in terms of natural functions, are relatively rare. An ordinance of DeKalb County, Georgia,[41] provides that "[A] combination of storage and controlled release of stormwater runoff shall be required for all development and construction which will increase the peak rate of runoff from the site by more than one cubic foot per second for a ten year frequency storm." The ordinance then sets performance standards for the rate of runoff by means of the following formula:

> The peak release rate of stormwater from all developments where retention is required shall:
>
> (1) not exceed the peak stormwater runoff from the area in its natural undeveloped state for all intensities up to and including the one hundred year frequency and all durations of rainfall; or
>
> (2) not be greater than that calculated for a storm of two-year frequency with a runoff coefficient of .20, .25, and .35 for land with an average slope of up to 2%, 2-7%, and over 7% respectively.

The ordinance also sets a performance standard for controlling the volume of runoff:

> "The live retention storage to be provided shall be calculated on the basis of the hundred year frequency rainfall as published by the National Weather Service for the affected area. The retention volume required shall be that necessary to handle the runoff of a hundred year rainfall for any and all durations from the proposed development, less that volume discharged during the same duration at the approved release rate as specified above."[42]

The ordinance does not tell the developer what kind of retention facilities to use; in this respect, it is entirely performance-oriented.

More succinctly, the policy of Medford Township, New Jersey is that "[n]o alternation will be permitted of the amount of surface runoff presently occurring, both under normal precipitation as well as under intense storm conditions, as identified in the Runoff Management Chart .... [e]xcess runoff is to be recharged locally into the ground through the use of recharge ponds or injection wells."[43] The Runoff Management Chart correlates vegetative cover type, soil type (in terms of both runoff and infiltrative potential), and relevant land use categories (e.g., 1-acre residential, 1/4-acre residential, intense urban), with excess runoff in inches produced during the most intense hour of a 10-year recurrent 24-hour storm, and with percentage of site area required for withholding that excess in order to allow its infiltration locally within 3 hours. The three-hour limit is deemed practicable in terms of the space required for rainwater retention in suburban development. A separate hydrological map shows current and permitted runoff for each area of the municipality as well as outcrops of important aquifers, which are protected by a prohibition against any increase in the very low runoff rates prescribed for them. With these technical aids, a developer can determine how to organize his site plan and what control mechanisms to adopt, without having to study the runoff problem from scratch.

The Medford Ordinance also provides that "soil loss [shall be] restricted to three tons per acre per year at all times including all stages of development." The three-ton limit was evidently recommended by USDA as capable of being met through feasible interceptive devices (e.g., dams or terraces) at or near the site. On this point, the ordinance refers the developer to a Potential Soil Loss Map which shows the potential loss in terms of tons per acre per year according to three different categories of soil types, moisture conditions, and steepness and length of slopes. A chart accompanying the map shows how calculated losses may be modified according to the type of vegetative cover. For example, if the site remains covered with grass, actual soil loss will be only 1.3% of the potential loss if the land is bare.

Alternatively, a developer might employ the so-called Universal Soil Loss Equation, which correlates factors for rainfall, length and degree of slope, erodability of soil, cropping and management techniques, and conservation practices. By calculating each factor and multiplying, this equation estimates the sheet erosion that will occur under different uses of the land.[44]

Another regulation of Medford Township provides that "[a]pplication of nutrients in the form of fertilizer, drainage from septic tanks and effluent leaking from sewers [shall be] restricted to types and amounts which can be absorbed by local vegetation and soils to ensure no increase in concentration of nutrients beyond present levels at the top of local seasonal high water table levels."[45] For meeting this requirement, the developer is referred to water-table and soil-permeability maps, as well as to maps of hydrological soil groups and cover types organized according to both their infiltrative capacity and their runoff potential.

Quantitative performance standards of the sort specified in the DeKalb and Medford ordinances, however, may be difficult to monitor and enforce. Their principal utility probably lies at the initial stage where a permitting agency reviews development proposals. At that stage, the agency can apply technical expertise -- which this approach assumes it will have at its disposal -- to determine whether the developer's proposed site plan, construction techniques and procedures for ongoing operation and maintenance will result in meeting the prescribed standards. Once an approved development is in place, unless sophisticated monitoring and inspection techniques are available and employed, compliance with the standards may have to be inferred from compliance with the plans, techniques, and procedures on which the development permit was originally conditioned.[46]

Where pure performance standards cannot readily be specified, it is still possible to prescribe standards for human activity that are closely related to the natural characteristics of the site. In general, the purpose of such standards is to minimize interference with natural functions, while allowing development to occur up to some point that is identified, expressly or by implication, as the natural carrying capacity of the site. For example, the Medford Township ordinance provides that where the seasonal high water table is 0-1 feet, no permanent habitation will be permitted; where 1-5 feet, septic tank drainage fields are prohibited and sewers must have leak-proof joints. Types and amounts of fertilizer application are also restricted in areas of high water tables. For three different classes of vegetative or forest type, maximum permitted clearings are established as percentages of the site area of development, and a minimum width of undisturbed vegetation is also required. For example, if the cover is a mature, deciduous lowland or floodplain forest, as shown on the Vegetation Management Map, and if the site area of development is 11-25 acres, then the regulation permits 55% of the area to be cleared. A 2-crown width must be maintained of the dominant mature species present on site. The Ecological Planning Study also includes a set of criteria for matching suitable land uses to natural profile types and a set of maps showing what areas are accordingly deemed suitable for forest and agricultural production, recreation, and development of various kinds.[47]

A mixed approach is illustrated by regulations of Mine Hill, New Jersey with respect to soils overlay. The purpose of these regulations

> "is to prevent inappropriate development from taking place ... in those areas characterized by certain soil types, slope and water levels without proper corrective action if possible. Inappropriate development in these areas increases soil erosion and sedimentation thereby intensifying flooding by clogging drainage structures. Sedimentation reduces reservoir life and destroys recreational use of water bodies."[48]

There follows a listing of soil types keyed to a soil survey map and showing opposite each type the problems and development limitations to which it gives rise. Some soil types are listed as "unbuildable," because of flood plain or excessive gradient. Others are described as having "severe development problems" because of poor drainage, high water table, erodability, or other natural characteristics. Structures and improvements of all kinds are prohibited on lands designated as unbuildable, and areas identified as having severe development problems are to be avoided "unless corrective action is indicated such as soil erosion and sedimentation control measures, storm water drainage systems, riprap and retaining walls, fills, excavations, and other appropriate improvements." Clustering of development units on larger tracts is encouraged so as to avoid development on soils that are indicated as unsuitable for this purpose.

The foregoing examples indicate the possibility of deriving standards for development from definitions of environmental functions or processes. In this manner, a community can evolve a set of land-use controls that will reconcile developmental with environmental objectives and that is likely to withstand challenge on constitutional grounds.[49] It should not be supposed, however, that development standards can automatically be inferred or deduced from environmental data; an exercise of judgment, informed by a community's land-use policy, will always be involved.

4.2.6 Erosion and Sedimentation Controls

Techniques of direct regulation are being applied by a growing number of communities "to sensitize development to the erosion/sedimentation potential of the site."[50] Ordinances requiring erosion and sedimentation controls as a necessary condition for development approval may be enacted under a separate enabling authority or by amendment to the community's basic zoning or subdivision ordinance. Where a community feels confident that a particular set of controls should be adopted for all developments of a designated class, or for all earthmoving activities that can be identified as having a high erosion potential, it will make sense to specify the necessary controls in the ordinance itself. Or they may appear in rules and regulations adopted by the appropriate state agency. Such regulations can be quite precise, despite the generality of their application. For example, regulations of the Pennsylvania Department of Environmental Resources require that:

> "Diversion terraces shall be constructed up-grade of a project area to convey runoff around the ... area. For temporary diversion the channel shall have the capacity to convey 1.6 cubic feet per second per acre of land tributary to it. For permanent diversion, the channel shall have the capacity to convey 2.75 cubic feet for each acre of project area tributary to it and shall be provided with a 24-inch freeboard. The basin shall be cleaned when the storage capacity of the basin is reduced to 5,000 cubic feet per acre .... Outlet structures shall be designed to pass a minimum flow of 2.0 cubic feet per second for each acre of project area tributary to the basin."[51]

More commonly, state or local regulations do not specify uniform controls for all development, but provide instead a set of principles for evaluating development and concomitant controls on a case-by-case basis, according to variable site characteristics such as type of soils, degree and length of slope, size and duration of exposed surfaces. Such principles may state, for example, that the smallest practicable area of land shall be exposed at any one time during development; that natural features shall be preserved whenever possible; that temporary vegetation or mulching shall be used to protect critical areas exposed during development and permanent final vegetation installed as soon as practical in the development process; and that development in general shall be fitted to topography and soils in such a way as to create the least erosion potential.[52] Accordingly, development proposed for steeper slopes or on soils of relatively high erodibility will be subject to stricter standards than equivalent development in flat terrain or on more resistant soil. In this manner, flexibility in the administration of the ordinance can be assured, taking account of a wide variety of possible interactions between site characteristics and types of development.

The ordinance may also refer the developer to a manual on erosion and sedimentation control, in which are set forth detailed guidelines or standard for various types of controls that could be incorporated into site plans, construction practices and ongoing maintenance procedures. The manual can be amended from time to time in light of experience and as new techniques are developed for controlling runoff and erosion, without having to go through the formal process of amending the ordinance itself every time a change is made in the technical guidelines. This approach has the dual advantage of furnishing detailed technical assistance to the developer while encouraging technical innovation. Assistance in preparing the manual can be obtained from the Soil Conservation Service of the United States Department of Agriculture and from a number of states (including Maryland and Pennsylvania) which have already developed detailed manuals for the use of their local governments.[53]

Typically, the ordinance provides that no land area may be disturbed until a plan for soil erosion and sedimentation control has been submitted to and approved by the relevant agency. This could be the planning department, the county soil district, the municipal building inspector, city engineer, planning commission, or even the town council, depending on "relevant state enabling legislation, the effectiveness and efficiency . . . and the capabilities of the evaluative body."[54]

Since the effectiveness of this type of regulation depends heavily upon the judgment of the reviewing body, "it is apparent that additional evaluative resources are required, such as a competent planning staff with some training in the soil sciences and soil conservation practices ...."[55] Soil conservation districts, where they exist, can assist in performing the necessary evaluations. Under some arrangements, "each application for development is required to have an erosion and sediment tion control plan in line with the standards established by the district. The district then evaluates the control plan and, in some cases, serves as the enforcement agent."[56]

A good example of an erosion and sedimentation control ordinance is the one adopted by Washington County, Maryland. It provides that "the surface of land in this County shall not be disturbed or changed for any non-agricultural purpose whatever ... except in accordance with a plan for control of erosion and sedimentation approved by the Soil Conservation District and a grading permit approved by the Building Permit Department of Washington County."[57] (In addition to agricultural practices and structures, the ordinance exempts from its provisions the construction of single-family residences or their accessory buildings on lots of two acres or more). With each application for a grading permit, the plan, specifications, and a time schedule must be submitted, accompanied by the applicant's certification that all land clearing, construction and development will be done pursuant to that plan. It must be prepared or approved and signed by a professional engineer, land surveyor, or architect. The plan and specifications must show topography and soil types, vegetative practices, a grading plan, proposed improvements, and provisions for erosion control both during construction and afterwards together with a schedule and sequence of operations. All grading plans and specifications must include provisions "in substantial accordance with" the Design Manual for Erosion and Sediment Control for Washington County.

If the application conforms to the foregoing requirements, the Soil Conservation District must approve the same and forward one copy of its written approval to the County Engineer, one copy to the Planning and Zoning Commission, and two copies to the Building Permit Department of Washington County, which then issues the grading permit to the applicant.

The ordinance further provides that the developer and all subsequent owners of the property "shall maintain all permanent anti-erosion devices, retaining walls, structures, plantings and other protective devices." To assure compliance with the ordinance and the permits issued under it, the County Engineer is to inspect the work done under approved plans and permits and to issue certificates of satisfactory completion to permittees.[58]

The approach adopted by DeKalb County, Georgia, is to specify at some length in the County Code standards to be observed with respect to erosion and sedimentation control, while leaving most of the details to the architect or engineer who prepares the control plans for submission along with a development application. For example, the ordinance provides that "[s]edimentation facilities (debris basins, sedimentation traps) and other control measures such as hay bales, berms, interceptor ditches, and terraces shall be installed in conjunction with the initial grading operations and be maintained throughout the development and construction process to remove sediment from runoff waters draining land under development." Land which has been cleared for development must be protected "by appropriate vegetation and land covering techniques such as seeding, sodding, [and] ground cover installation ...." No grading, cutting, or filling is allowed on any site under development if it will result in bringing unprotected land surfaces into contact with surface water, "unless erosion control and sedimentation control devices can be installed between the grading area and water surface ...."[59]

An ordinance can combine specifications for control measures with some degree of orientation toward natural performance standards. For example, it could be required that the erosion and sedimentation control plan result in runoff and erosion no greater than would occur if the land had remained in its natural state. To that end, the ordinance could direct that the developer use, to the maximum feasible extent, natural control features such as existing swamps and swales; that he employ cluster development where practicable in order to reduce the total area of impervious surface and to preserve open spaces and topographical features that are critical to surface water management; that he avoid concentrations of flow, take steps to dissipate runoff velocities, and reestablish vegetative cover as soon as possible after land disturbance; and that he adhere strictly to any applicable requirements for designated critical areas. While specifying certain design standards, the ordinance could at the same time allow innovative control devices to be employed if their performance capabilities, as shown by engineering analysis, would meet the objectives of the regulation.[60]

Erosion and sedimentation controls need not and should not be confined to districts of critical planning concern. Such controls may be needed throughout a community in order to prevent the migration of sediments from one location to another. Thus, controls of this sort can usefully supplement other types of land-use regulation.

4.2.7 Controls Over Land Disposal of Wastes

A growing number of states have adopted detailed regulations on the siting, operation and maintenance of municipal landfills. Such regulations are designed in large measure to avoid pollution of ground or surface waters from leachate or overflow at landfill sites.

Regulations of the State of Hawaii[61] prohibit establishment or operation of any solid waste disposal facility without a permit from the State Director of Health. A permit application must be accompanied by detailed plans for the facility and by a plan of operations. Permittees are required by these regulations to compact and cover all solid waste accumulated after each day's operation with earth or other approved material so as to safeguard the environmental quality of the surrounding area; to have monitoring equipment in place to detect any pollution that might result from the facility; to maintain a minimum vertical separation of five feet between deposited waste and high groundwater table; to provide for minimizing the flow of offsite drainage over the landfill; and to deposit solid wastes in such a manner as "to prevent waste materials, leachate or eroded soil particles from entering the waters of the State without receiving the best practicable treatment or control."

Landfill regulations might also prohibit acceptance of infectious or other hazardous wastes; prohibit lagooning of sewage, sludge or seepage; establish limits on the width of the working face; and require operators to meet periodic self-monitoring, recording, and reporting requirements.[62] Numerous further points of control could be cited from regulations of one or another state. Their coverage and detail can be as extensive or as selective as a state may deem practicable for its own purposes.

Direct regulation of solid waste disposal is a traditional form of government control that is fairly easy to comprehend. The difficulties it has encountered are rather of a practical nature. In some states, "grandfather clauses" exempt pre-existing dumps and landfills from new state regulatory requirements. This loophole can only be filled by regulation at the local level, which is often inadequate. Moreover, regardless of the division of responsibility between states and localitites, substandard operation of landfills is commonplace in many parts of the country and compliance with strict regulatory standards has been difficult to secure. Many landfills have been located next to water bodies, on wetlands, or over aquifers, which inevitably become polluted as ever increasing volumes of solid waste are brought to those sites for disposal. Closing down a landfill operation is a feasible remedy only if alternative disposal sites or methods are available, and often they are not because of land scarcity, obstacles to regionalization, or impracticability of recycling. Regulation, then, needs to be accompanied by more forceful regional planning and a set of incentives for employing different approaches to the problem of solid waste pollution. Until then, however, state and local governments could be doing a better job of monitoring compliance with and enforcing feasible operating standards for municipal landfills.

Regulation of septic tanks is another largely local responsibility that many communities have not adequately met. An effective regulatory scheme would prevent pollution of ground or surface waters from failing septic tanks through a permit system that controls their location, density, construction, and maintenance. State health codes routinely address these subjects, but may be deficient in a number of respects. For example, rapid percolation may be required in order to avoid nuisance condition or health hazards from surface contaminants, but if percolation of wastes is too rapid they may pollute ground waters. Scavengers (those whose business it is to clean out septic tanks) ought to be licensed and required to report their sludge disposal sites and methods to the licensing body, but effective regulation of scavenging practices is not found in many states. Local boards of health are supposed to regulate septic tanks through local health ordinances that implement, at a minimum, the standards set forth in the state code, but pressures for development combined with reluctance to pay for new or expanded sewer systems often result in permitting septic tanks on unsuitable soils or in excessive densities. Enforcement of standards for septic tank maintenance is also practically nonexistent in many areas. The problem lies not in learning what can be done, as a regulatory matter, to prevent pollution from septic systems, but in mustering the political will and administrative resources that are necessary to bring them under control.

4.2.8 Control of Inplace or Accumulated Sources

For residues such as street litter, fertilizers and pesticides, highway salts, and oil spills onto paved surfaces, the most effective controls may be upon introduction of these substances into the environment rather than upon their migration after they have become waterborne.[63] Where threshhold prevention is not practicable, it will still be true, by and large, that the earlier the point in time at which controls are applied, the more effective they are likely to be.

A municipality might adopt an ordinance banning outright the application of certain fertilizers, pesticides, or road salts, or requiring that their use be conditioned upon restrictions to be set forth in a use permit. Runoff of these substances might largely be avoided by restricting the timing, quantity and methods of application, or by onsite collection and treatment prior to discharge. Gas stations and parking lots can also be required to trap runoff in onsite collection basins and to treat the collected flow for removal of oil, lead, and other offensive substances before discharge to storm sewers or to receiving waters. At a minimum, such controls might be prescribed for automobile-attracting facilities located near public water supplies.

Consider also the advantages of professional licensing systems for handlers and users of pesticides and other toxic materials as well as for carters of sludges from septic tanks and other waste treatment processes. A license would be awarded only to a person who demonstrated competence in the handling of such materials, and it could be revoked for failure to comply with applicable regulations designed to prevent their introduction into ground or surface waters.

It may well be, however, that controls of the foregoing varieties will be effective only if adopted at the state level. In the alternative, it may be necessary for a group of municipalities to agree upon the adoption of parallel or identical ordinances in order to make measurable progress in controlling these pollutants. The same can be said of all nonpoint sources whose effects are cumulative rather than discrete, or diffuse rather than confined to particular areas.

Where road salts are applied by state or local highway departments, a shift in operating policy may be called for, rather than any fresh enabling or regulatory legislation. Sand may function as well as salt on icy roads in wintertime, and sand is easier to pick up or to trap in sedimentation basins after the winter has passed.

Anti-litter ordinances and coordination of street-cleaning programs with parking restrictions can be instituted at the municipal level. In many jurisdictions, the prinicpal obstacle to cleaner streets, with resulting improvements in the quality of water resources, is not absence of regulatory authority but lack of will to fund and enforce the necessary restrictions.

4.3 Legal Issues

This final section addresses two sets of legal issues surrounding the implementation of a number of the above regulatory approaches: securing compliance on the part of private developers, and protecting their various constitutional rights in the process.

4.3.1 Securing Compliance Through Monitoring, Maintenance, and Enforcement of Controls

The principal weakness of many regulatory schemes is that they fail to include adequate provisions for securing compliance on the part of those to whom they are addressed. This problem arises especially where compliance is not just a one-shot matter, but consists of continuing activity or forbearance over time. Regulations can address the problem by requiring, for example, that those who undertake land uses or land-disturbing activities likely to affect water quality must maintain control facilities in good working order, install monitoring devices, record operating data, and submit periodic reports to the regulatory agency. Any number of self-monitoring requirements can be included in a set of administrative regulations, and the agency can reserve the right to inspect premises for compliance, even in the absence of a permit system.

However, regulations of general applicability combined with permits to be issued on a case-by-case basis are a superior type of control strategy. This is so for several reasons:

- A permit system has the initial advantage of prohibiting certain types of land use or land-disturbing activity except upon compliance with prescribed conditions. The proponent of the activity has the burden of applying for a permit and of indicating in his application and accompanying plans how he will meet pollution-control requirements.

- The process of applying for and receiving a permit makes the applicant fully aware of what is required of him; he cannot thereafter plead ignorance of the law.

- The issuing authority can write special or particular conditions into a permit, tailor-made to the applicant's situation. Regulations alone, by contrast, tend to be of general applicability and therefore cannot cover all cases or contingencies without growing cumbersome.

- Issuance of a permit can be made conditional upon the posting of a performance bond by the applicant. Such a bond, executed by a surety, can be used (for example) to guarantee the faithful execution of a site plan, undertaking of runoff and erosion control measures, or compliance with other conditions specified in the permit. The bond may be deposited with the fiscal officer of the issuing government. If a default occurs in the performance of any term or condition of the permit or bond, and if compliance is not achieved within the time specified in a notice of default, the issuing government may proceed without delay to use the cash deposited for completion of the required work. By its terms, the bond obligates both the permittee and his surety for payment of all necessary costs incurred by the government to correct noncompliance. Moreover, if the cost of the work exceeds the amount of the bond, the permittee remains obliged to pay the excess.

- For significant violations, a permit can be revoked or the permitting authority may fail to renew it upon expiration. These possibilities can serve as powerful inducements to compliance.

Whether by permit or by regulation alone, the responsibility to maintain control facilities in good repair needs to be clearly spelled out. Ordinarily, the land user has that responsibility, but it may be provided that the municipality will construct and maintain certain facilities (e.g., a retention pond) for which the costs will be passed on to the participating land users in the form of special benefit assessment.

The regulatory system should provide for official inspection of control facilities upon their completion and prior to giving them final approval. Unannounced inspections should also be made from time to time thereafter, in order to monitor continuing compliance and to check the veracity of self-monitoring reports submitted by permittees. In particular, employees of the appropriate government agency should be expressly authorized to enter upon and inspect subject properties at all reasonable times. Ideally, they should further be empowered to make emergency repairs to any malfunctioning facility and to charge the owner for the costs if proper maintenance is his responsibility.

The Maryland Department of Water Resources has published a Sediment Control Inspectors Handbook, which could be adopted in all jurisdictions.[64] The handbook tells the inspector how to prepare himself for the intelligent performance of his task. He should be thoroughly familiar with the details of the governing ordinance, with the approved sediment control plans, and with methods of construction and capabilities of control equipment. Establishment of local training programs for inspectors is recommended by the handbook. It includes a sample field inspection form and final inspection report. Compliance should not, however, await inspections. "Whenever possible, prior to grading, schedule a meeting with the field superintendent to review the sediment control plan, explain what should be done, and the timing involved. Such a preliminary meeting will go a long way towards establishing necessary understanding and averting needless confusion." The handbook also contains useful guidelines on what to look for during an inspection and whom to contact when violations are discovered. Informal communication and cooperation between inspectors and permittees can go far toward securing compliance without the need for formal enforcement action in most cases.

The regulations should spell out enforcement procedures to be followed in the event of noncompliance. For example, the erosion control ordinance of Leon County, Florida[65] provides that if the County Environmental Administrator finds a violation of an approved site plan with respect to clearing and development, a failure to construct or maintain the required control measures, or a failure to obtain initial approval of development, he is authorized to issue written notice to the violator of the nature and location of the alleged noncompliance and to specify what remedial steps are necessary. If these are not promptly taken by the violator, the Administrator may then issue a stop-work order "to cease and desist all or any portion of the work upon all or any geographical protion of the project which is contributing to on-site generaged siltation or sedimentation or runoff, except such remedial work as is deemed necessary to bring the project back into compliance." Violation of a stop-work order may lead to revocation of the permit, thereby rendering the land user liable to civil or criminal penalties. Any person violating the ordinance or a stop-work order issued thereunder "shall be punished according to law. Each day such violation continues shall constitute a separate offense. Any person may seek an injunction against any violation of the provisions of this ordinance, and recover such damages as he may suffer, including but not limited to the cost of removal of any debris or sedimentation caused by such violation." This provision incorporates by reference the criminal statutes applicable to the violation of any county ordinance, and also makes clear that injured parties may seek damages in a tort action. The ordinance of Washington County, Maryland[66] provides more explicitly that violators "shall upon conviction be guilty of a misdemeanor, punishable by fine of no greater than $500 and each day of violation shall be considered a separate offense."

Civil penalties are also possible, in lieu of or in addition to criminal ones. The authority of a municipal government to establish penalties for particulr types of violations should be checked out. If the penalty limits prescribed or allowed under state law are low or if no penalties can be assessed for violations, a high level of compliance may be difficult to achieve. In such a case, amendments to state law, providing for significant penalties as well as for injunctive relief through the courts, can help to show that the state and its political subdivisions mean business.

4.3.2 Constitutional Questions

4.3.2.1 Takings

As already noted, private property may not be taken for public use without just compensation. The question whether a taking has occurred may arise in any case where uses of private property are restricted for environmental objectives. The law on this subject is in a state of flux and it varies considerably from state to state. It is therefore necessary to refer to the judicial precedents of the federal courts and of your state courts before deciding where the line may be drawn between valid restrictions imposed in the exercise of the police power and restrictions that may be invalidated as takings with respect to a particular piece of property.[67]

A trend can perhaps be observed in recent case law to the effect that a landowner is not entitled to convert his property to its most profitable use by changing its natural characteristics, if the results of such a change would be harmful to the public welfare.[68] Increasingly, the right of the public to have natural resources preserved in undegraded condition is being recognized. The courts are beginning to perceive that there are natural and unnatural uses of particular lands, that land and water resources are closely interrelated, and that the public has an important stake in preventing interference with these relations. Thus, it is said that "[a]n owner of land has no absolute and unlimited right to change the essential natural character of his land so as to use it for a purpose for which it was unsuited in its natural state and which injures the rights of others."[69] While the securing of benefits not previously enjoyed by the public is still thought to be a taking, it can perhaps be distinguished from avoidance of damage to public interests in the environment -- a legitimate objective of the police power. If a regulation can be characterized in terms of damage avoidance, it stands a fair chance of being upheld although it deprives property owners of profits or even reduces substantially the market values of their lands. There are limits, however, even to this emerging doctrine; a taking may still be deemed to have occurred where the restriction "practically or substantially renders the land useless [to the owner] for all reasonable purposes,"[70] especially if the land had some commercial value to begin with apart from the possibility of converting it artificially to some new and "unnatural" use.

The lessons to be learned from these cases are that the risk of invalidation by the courts can be minimized if your regulatory scheme (a) is demonstrably based on avoidance of injury to the public at large from irresponsible uses of private property; and (b) consistently with that objective, still leaves the owner free to put his land to one or more reasonable uses. It will also help if the regulation can be justified in terms of public health and safety (e.g., protection against flood damage, purity of water supplies) and not merely of aesthetics or other less tangible aspects of public welfare.[71] Moreover, as indicated in the *Ramapo* and *Petaluma* cases, use restrictions are more likely to be upheld if they are of only temporary duration.[72] In general, performance or specification standards, precisely geared to environmental objectives, will have the best chance of surviving constitutional challenge because they do not rule out most land uses (even though they may well increase the costs of development).

4.3.2.2 Substantive Due Process

A regulation may be declared unconstitutional if its provisions are arbitrary or unreasonable, bearing no substantial relation to the public health, safety, or general welfare. In other words, regulations must be based on legitimate governmental purposes and be reasonably calculated to accomplish them. For example, large-lot zoning may be acceptable if its purpose truly is to avoid excessive concentrations of septic tanks on soils of limited absorptive capacity, but not if its underlying purpose is to halt growth in a town or to exclude lower-income groups.[73] Such measures should therefore be based on objective data which will tend to justify both the ends and the means. Assuring the constitutional validity of land-use restrictions and requirements is a major reason for local governments to incorporate natural resource inventories or ecological planning studies into their decision-making processes.[74]

4.3.2.3 Equal Protection

States and their political subdivisions are constitutionally prohibited from denying to any person the equal protection of the laws. Since environmental regulations frequently restrict some persons to a greater degree than others, they may run a risk of being invalidated because of unreasonable, arbitrary, or invidiously discriminatory *classification* for regulatory purposes. "The basic principles of the equal protection doctrine are well established: any state or municipal legislative classification must be a rational one, bearing a reasonable relationship to a proper legislative purpose."[75] Thus, for example, properties designated as critical water-related lands (riverbanks, wetlands, aquifers, steep slopes) could be made subject to special use restrictions without running afoul of this constitutional standard, so long as the restrictions are essential to sound environmental management in the public interest. Here, then, is another constitutional reason for gearing land-use controls to natural resource inventories or ecological planning studies. It should be added that a municipality need not regulate all instances at once in which a problem of a particular type is shown to exist. Regulation has to begin somewhere, and there is no constitutional infirmity in a piece-meal approach that is free of ulterior discriminatory motives.

4.3.2.4 Procedural Due Process

As already noted, local governments ordinarily derive their powers to act from enabling statutes of their state legislatures. Such delegated powers must be exercised not only for approved purposes but in accordance with prescribed statutory procedures. These may require, for example, that a local agency give advance public notice and opportunity for public hearing on proposed legislative or regulatory action; that it adhere to prescribed voting procedures; that it afford opportunity for adjudicatory hearing on proposed issuance or denial of permits; and that it base certain types of decision on a judicially reviewable record. Even where state law does not require such procedures, it is a good idea to adopt them for the sake of clarity, fairness and openness in decision-making.

If an agency is to administer a permit system or to pass upon proposed development plans, its regulations should clearly indicate who must apply for approval, what information must be included on the application form, within what time-frames it must be submitted and will be acted upon, and according to what criteria permission will be granted or denied. It is a fundamental tenet of due process that agencies structure the exercise of their own discretion in accordance with impartial rules.

A definite trend can be observed, in judicial case law, toward requiring local governments to honor elementary concepts of due process in local decision-making. State Administrative Procedures Acts are ordinarily applicable only to agencies of state government, but the courts have shown an increasing willingness to scrutinize local decisions as well by reference to APA-type standards.

4.3.3 Eliminating Windfalls and Wipeouts

Government decisions often have the effect of conferring gratuitous benefits on some people and losses on others. For example, restrictions on development of water-related lands may substantially reduce their market value, without going so far as to constitute a compensable taking. Conversely, the clean-up of a waterway or the location of a new highway can greatly increase the values of adjacent properties. Thus, public benefits are secured at private expense, and private benefits at public expense. The perception of such inequities in the distribution of costs and benefits can forestall or derail government decisions for want of political support. Predictably, this type of problem will become more acute as local governments increasingly restrict land-use for water quality and other environmental purposes.

To remedy windfalls and wipeouts resulting from government decisions, a number of schemes have been proposed, some of which may be feasible for local governments to adopt. In general, they are premised on the idea that government can recapture a part of the economic benefit it confers on some property owners and use the proceeds to compensate others to whom it occasions losses. For example, developers who are favored by zoning decisions could be required to contribute to a special fund for that purpose. Alternatively, the government could establish and administer a market in transferable development rights (TDRs), which works on the principle that owners of developable land must purchase such rights, as a prerequisite for development, from those whose land is to be preserved as open space. "At optimum efficiency, this device, like zoning, requires little expenditure of public funds for implementation other than administrative costs, and is thus less costly than the conservation restriction method .... The municipality is in effect the middleman. It merely allocates development rights equitably among parcels of land."[76]

It is not enough to think only of regulating sources of pollution. Governments must also consider how to remedy the unintended but inequitable consequences of regulatory control. The same holds true of public investment decisions and other components of programs to promote environmental quality.

REFERENCES

1. They are discussed in Section 4.3.2 below, and are mentioned at a number of points in this chapter's presentation of strategic alternatives.

2. Ohio Constitution, ART. XVIII, Sec. 3.

3. Such a statute in Rhode Island was cited in the case of *Wood v. Peckham*, 80 R.I. 479, 98A. 2d 669 (1953).

4. U.S. Department of Commerce, *Standard State Zoning Enabling Act* §§ 1,3 (revised edition 1926). With minor modifications, this model has been adopted by most states.

5. 469 F. 2d 956 (1st Circ. 1972)

6. The court observed, hoever, that a desire to avoid further growth would not be a legitimate basis for restrictive zoning. Other cases indicate, moreover, that large-lot zoning may be invalidated if it prevents owners from making any practical use of their land or if it is motivated by a wish to exclude persons deemed undesirable on racial or socio-economic grounds. For these reasons, large-lot zoning and other measures restricting land use must be clearly warranted by available data in support of an avowed municipal purpose to prevent environmental degradation.

7. Edward J. Kaiser and Peggy A. Reichert, "Land Use Guidance System Planning for Environmental Quality," 15 Natural Resources Journal 529, 557 (1975).

8. *Ibid*.

9. See *Management and Control of Growth*, Urban Land Institute (1975), Volume II, p. 344.

10. *Ibid*., p. 346

11. 30 N.Y. 2d 359, 334 N.Y.S. 2d 138 (1972).

12. See the discussion below, Section 4.3.2.1

13. See Daniel R. Mandelker, *Managing Our Urban Environment--Cases, Text and Problems* 878-904 (Bobbs-Merrill: 1966).

14. See the discussion below, Section 4.2.4

15. Ky. Rev. Stat. § 83.330 (1962)

16. N.J. Stat. Ann. 13:8A-30(d) (Supp. 1973)

17. Bucks County Planning Commission, "Plan for Implementation of Provisions of Act 515 of 1965" (Doylestown: Bucks County Planning Commission, February 3, 1971).

18. M.G.L. Ann. Ch. 184, §§ 31-33 (Supp. 1974). The description in the text of the Massachusetts law is taken from Russell R. Sicard, "Pursuing Open Space Preservation: the Massachusetts Conservation Restriction," IV Environmental Affairs 481-514 (Summer 1975). Mr. Sicard's article discusses various legal ramifications of the device in some detail.

19. One important effect of this statute is to supercede ancient common law limitations on the extent to which the alienability and use of land can be restricted over time.

20. Sicard, Ibid., p. 492

21. See Sicard, Ibid., p. 497

22. 30 N.Y. 2d 359, 334 N.Y.S. 2d 138 (1972)

23. 522 F. 2d 897 (9th Cir. 1975)

24. An extensive literature has developed upon the Ramapo and Petaluma cases. See e.g., Robert W. Burchell and David Listokin, Future Land Use 59-140 (The Center for Urban Policy Research at Rutgers - The State University of New Jersey, 1975); David Falk and Herbert M. Franklin, "Local Growth Management Policy: A Legal Primer," (The Potomac Institute, Washington, D.C., 1975); II Management and Control of Growth (The Urban Land Institute, Washington, D.C., 1975).

25. Harristown, Illinois, Zoning Ordinance, Section 3.1, 1972. It should be emphasized, however, that if a land owner in a conservation zone is deprived thereby of all practical use of his property, the zone may be deemed invalid as taking of that property for public purposes without compensation. See the discussion below, Section 4.3.2.1.

26. See the discussion below, Section 4.1.7, 4.2.8.

27. See the discussion of natural performance standards below, Section 4.2.5. A natural resource inventory and a reliable environmental data base are virtual prerequisites for the effective use of this technique, whatever the nature of the special district may be and whatever the form in which concomitant land-use regulations may be specified.

28. Wis. Stat. 59.971, 144.26 (1966-67).

29. The description of the Wisconsin program in the text, including quotations from applicable laws or regulations, is taken from Fred Bosselman and David Callies, The Quiet Revolution in Land-Use Control 235-55 (U.S. Council on Environmental Quality, December 15, 1971). The principles of this program could be adapted to incorporated urban or suburban municipalities, with appropriate adjustments in coverage and detail.

30. Reproduced in *Performance Controls for Sensitive Lands: A Practical Guide for Local Administrators* 81-86 (U.S. Environmental Protection Agency: March 1975).

31. See the discussion below, Section 4.2.4.

32. Environmental impact assessments at the local level may, but generally will not, have to include considerations of alternative sites, comparative cost/benefit analyses, and other planning elements found in EISs prepared under the National Environmental Policy Act (NEPA) or comparable state laws. The options and resources available to local developers ordinarily will not be sufficient to warrant making them prepare full-scale NEPA-type statements.

33. Subdivision Regulations of the Town of Lincoln, §§ 3.2.3.1 - 3.2.3.3

34. Township of Medford, Ordinance 1974-11, §2

35. They are discussed in detail below, Section 4.2.5

36. 10 V.S.A. Chap. 151, §§ 6001-6091.

37. Robert H. Twiss, "Commentary--Nine Approaches to Environmental Planning" in *Future Land Use*, *Op. Cit.*, 20, supra, p. 239.

38. *Op. cit.*, see footnote 30 above. This excellent study, prepared for EPA by the American Society of Planning Officials, should be read from cover to cover by all 208 planners. It provides a number of examples used in the text of the present report, as well as a useful framework for evaluating alternative types of regulatory control.

39. *Ibid.*, p. 445.

40. See, e.g., the bibliographical references listed in *Ibid.* at 472-73 and at the conclusions of the various chapters of the same report.

41. This ordinance is discussed in *ibid.*, on pp. 459-60 and its text appears on pp. 481-89.

42. The choice of the 100-year storm in the DeKalb ordinance as the basis of setting rate and volume standards is questionable. Retention of so large a storm may require substantial over-capacity in the control facilities and could conflict with sound principles of flood management. Experts in this field should be consulted before deciding upon the formulae to be employed.

43. Narendra Juneja, "Performance Requirements for the Maintenance of Social Values Represented by the Natural Environment of Medford Township, N.J.," p. 29; Center for Ecological Research in Planning and Design, Department of Landscape Architecture and Regional Planning, University of Pennsylvania at Philadelphia.

44. The Universal Soil Loss Equation is discussed in some detail in Performance Controls for Sensitive Lands, pp 462-468.

45. Ibid., at 27.

46. Our observations in this paragraph are admittedly speculative; limitations on time and resources prevented us from ascertaining how these ordinances are actually working in practice. DeKalb and Medford should be directly consulted by any community contemplating similar approaches.

47. For further discussion of the performance standards approach as advanced by Ian McHarg, see Rice Odell, "Carrying Capacity Analysis, Useful but Limited," III Management and Control of Growth 22-28. "McHarg and his associates have determined what specific tracts of land have to offer, what their limitations are, and where development might best fit in." Ibid., 24.

48. The Mine Hill ordinance is reprinted in Performance Controls for Sensitive Lands, pp. 417-419.

49. See the discussion below, Section 4.3.2.

50. Performance Controls for Sensitive Lands, p. 60.

51. Title 25, §102.23 of the Rules and Regulations of the Pennsylvania Department of Environmental Resources.

52. E.g., the ordinances of Camden, J.J., described in Performance Controls for Sensitive Lands, pp 62-63.

53. For a selective list of publications on standards for erosion and sediment control, see Performance Controls for Sensitive Lands, pp. 67-69.

54. Ibid., pp. 60-61.

55. Ibid., p. 63.

56. Ibid., p. 65.

57. This ordinance is summarized in The Maryland Sediment Control Program--Assembly of Reference Items 75-80 (U.S. Dep't of Agriculture, Soil Conservation Service: College Park, Md. 1971).

58. The subjects of maintenance, monitoring and enforcement are further discussed below, Section 4.3.1.

59. For other examples of erosion and sedimentation control ordinances, see the Model Municipal Land Disturbance Ordinance, prepared by the New Jersey State Soil Conservation Committee and reprinted in *Performance Controls for Sensitive Lands*, pp. 87-91; the Soil Erosion and Sedimentation Control Manual of the Pennsylvania Department of Environmental Resources, January 1, 1974; the assembly of reference items entitled, "The Maryland Sediment Control Program," 1971, U.S. Department of Agriculture, Soil Conservation Service, College Park, MD; and a publication of Leon County, Florida, January 1975, entitled, "Environmental Criteria for Erosion and Sedimentation Control."

60. The foregoing approach is embodied in a model ordinance prepared by the South Branch Watershed Association of Clinton, N.J.

61. Hawaii Environmental Laws and Regulations, Volume II, Chapter 46.

62. E.g., New Jersey's highly detailed Solid Waste Management Regulations, adopted as Rules of the Bureau of Solid Waste Management, N.J. Code Ann. 7:21-1 *et. seq*.

63. See, e.g., Harrison C. Dunning, "Pests, Poisons, and the Living Law: The Control of Pesticides in California's Imperial Valley," 2 *Ecology Law Quarterly* 633-693 (Fall 1972), for a detailed analysis of a use permit and licensing system whose general features could also be adopted for the preventive regulation of other nonpoint sources.

64. Maryland Department of Water Resources, Sediment Control Workshop, January 28-29, 1971.

65. Leon County Ordinance No. 73-10, as amended by Ordinance Nos. 73-57 and 75-5.

66. Cited above in footnote 57.

67. Ordinarily, the courts will not invalidate such a restriction in all its applications but only with respect to a particular property at issue in a lawsuit.

68. E.g., *Just* v. *Marinette County*, 201 N.W. 2d 761 (Sup. Ct. Wis. 1972); *Sibson* v. *State*, 5 ELR 20300 (Sup. Ct. N.H. 1975).

69. *Just* v. *Marinette County*, see footnote 68.

70. *Ibid*. On this point, see also *Morris County Land Co.* v. *Parsippany-Troy Hills Township* 40 N.J. 539 (1963), 193 A. 2d. 232.

71. E.g., *Turnpike Realty Co.* v. *Town of Dedham*, 284 N.E. 2d. 891 (Mass. 1972). The reader is also referred to the extensive literature on this subject. Fred Bosselman, David Callies and John Banta, *The Taking Issue* (Council on Environmental Quality: Washington, D.C. July 9, 1973) is an excellent starting point.

72. See the discussion above, Section 4.2.2, and *Steel Hill Development Inc.* v. *Town of Sanbornton*, 469 F. 2d 956 (1st Cir. 1972).

73. See the discussion of the Ramapo and Petaluma cases above, Section 4.2.2.

74. See the discussion above, Section 4.2.3.

75. Ronald M. Hershkowitz, "Local Environmental Protection: Problems and Limitations," *Environmental Affairs* (Vol. II, No. 4: Spring 1973), pp. 783, 793.

76. Sicard, *Op. Cit.*, n. 14, *supra*, 504. There is an extensive literature on the subject of TDRs, e.g., Jerome G. Rose, "A Proposal for the Separation and Marketability of Development Rights as a Technique to Preserve Open Sapce," 2 Real Estate Law Journal 635 (1974).

5.0 FINANCIAL CONSIDERATIONS

Carrying out preventive approaches to urban stormwater management requires adequate funding. The purposes of this chapter are: to identify specific funding needs and alternative sources; and to help local planners evaluate these financing options.

Two types of activities require funding regardless of the particular preventive approach taken:

- Continuous Planning
- Implementation and Enforcement

and thus will be discussed separately in sections 5.1 and 5.2. The remainder of the chapter (5.3.1-5.3.5) concentrates on five examples of typical stormwater pollution problems, in each case discussing funding needs, sources, and options for several alternative solutions. The five example problems discussed are:

- Pollution of groundwater supply due to development in an aquifer recharge area;
- Existing and projected development in an urban drainage area, leading to increased runoff containing increased contaminants;
- Projected development in a relatively undeveloped area causing increased runoff and increased contaminants in receiving waters;
- Development adjacent to a stream, causing stream bank erosion as well as introducing sediment and contaminants into the water;
- Development in and near wetlands.

In order to evaluate alternative funding options, explicit criteria are called for. Four criteria commonly used to evaluate government revenue measures are: (1) revenue adequacy; (2) social equity; (3) economic efficiency; and (4) administrative simplicity. As with levies for other public activities, funding approaches for urban stormwater management should be designed to meet these tests.

Revenue Adequacy: The basic objective of any levy is to obtain sufficient revenue to meet costs of providing service. Hence, the funding system should be designed to reflect the financial implications of inflation, technological advances, system improvements, additional loads, and shifts in preferences. It seems reasonable to expect that costs of services, such as stormwater management, will generally tend to increase over time; thus, a funding system should be able to cope with these changes in revenue requirements with a minimum of restructuring.

Social Equity: The question of what constitutes a fair tax or charge system is not a matter of technical economics but of personal preference and philosophy. Nevertheless, some principles have been delineated that offer a framework for analysis. The benefit principle and the principle of ability to pay are the most common bases for discussions of equity.[1]

Justification for service charges is generally based upon the "benefits received" principle which states that charges should be related to the benefits received from government by an individual or firm. People pay for goods and services received in the private economy, the argument runs, so why not in the public sector as well? If a charge system violates the benefits principle, then public services become a form of subsidy for their users, since the services are obtained at the expense of other people. Although equity is a basic underlying idea for application of the benefit principle, this form of levying charges also provides a substitute for the market test. If people who will benefit from expenditures are unwilling to pay for them, presumably they are not worth their cost and should not be undertaken.[2]

Implementation of the benefit principle is difficult because of the problem involved in quantifying the benefits of service and identifying all the beneficiaries. Three methods for deriving benefits have been suggested. One approach is to estimate a demand curve for the service and compute its value. Another approach is to estimate the cost of the best alternative method. A third approach is to interpret the benefits received principle as a cost occasioned method where those using the service are charged an amount equal to the cost of providing service to them.

Each of these approaches presents problems in implementation. To estimate a demand curve requires that the service be marketed through the price mechanism. To do this presents two problems. First, there is usually a single seller of this service. Second, public health and other factors make the purchase of a uniform level of service compulsory. To estimate the cost of the best alternative method requires that a reasonable alternative be available. It is not clear that such an alternative could be chosen and if it were the difficulties in estimating its costs would be formidable.

Because of the problems surrounding methods for estimating benefits received directly, the cost occasioned approach has had to suffice for implementing equity in sewerage service charges. This interpretation of the benefits principle assigns a charge to users equal to the cost of providing them with the service.

Economic Efficiency: Governments frequently use taxes and user charges as tools to achieve economic objectives. The charge procedure employed may affect economic efficiency through its influence on business decisions regarding location, production process, and output level. These decisions certainly carry implications for the efficiency of the economic system.

From a theoretical standpoint, the goal of economic efficiency is served when the price of each good and service produced equals the marginal social cost incurred in producing and marketing it (i.e., the social value foregone when the resources are diverted from alternative economic activities). For this reason, service charges would be equated at the margin to the social cost of collecting, transmitting, and/or treating the stormwater runoff. If the charge is not equal to the marginal social cost, then economic efficiency will be reduced. For example, if the charge is greater than the marginal social cost, firms requiring a large quantity of service will be placed at a competitive disadvantage due to rising costs. Unless they can reduce other production costs or raise product prices, their profits will decline. If they choose to increase product prices, the distortion created by the charge is shifted forward to the consumer. If the firm elects to reduce production costs, the distortion is shifted backwards to the factors of production. For example, a reduction in production costs may be accomplished by lower wages paid to labor. The extent of these shifts depends on the elasticities involved.

On the other hand, if the charge is lower than the marginal social cost, the production costs faced by a firm will be artificially low and profits artificially high. In this instance, the burden of managing the stormwater runoff problems generated by the firm is shifted to society. In the event that revenues resulting from charges levied as outlined above prove inadequate to cover the user's share of costs, additional levies that are independent of the marginal cost for service may be addressed to the user.[3]

Administrative Simplicity: A funding procedure should be easy to understand and enforce, be acceptable to users, and involve reasonable compliance costs. The basis for the levy should be easily understandable by all who are subject to it. Payment should be able to be verified and the charges not impossible to collect. The funding system should be consistent with generally accepted "rules" of fair play, and the charge for service should compare favorably with the customer's perception of the value of services received. Finally, compliance costs should be low. From the viewpoint of the management agency, this means that the charge system should be inexpensive to administer (i.e., low computation costs, no expensive inspection). From the customer's perspective this means convenience of payment.

These criteria will be applied to the funding alternatives discussed in the five sample problems. They can also usefully be applied by local officials considering their own funding options for meeting a much wider range of stormwater management problems. However, several additional constraints on their use should be noted.

In describing financing methods for various approaches, reference is frequently made to landowners within the drainage area or area benefited by the adopted approach. In many instances, these "areas" will not coincide with existing political subdivisions. Thus, intergovernmental cooperation agreements, either voluntary or mandated, will have to be utilised. As an alternative, special purpose political subdivisions such as drainage districts or soil conservation districts may provide the institutional framework for financing. The needed institutional arrangements may require enabling legislation.

In approaches which utilise the "police" power of the government to control land use, there is the problem that the constraint on use is so restrictive that a "taking" occurs. If it is deemed a "taking" either the constraint may not be enforced or the land owner must be compensated. The first possibility defeats the purpose of the approach altogether, while the latter possibility requires expenditure of public funds. Thus, the use of these constraints must be undertaken with great care. Aside from the legal problem, a sense of fairness may require compensation to the land owner who is severely constrained to benefit or protect the public.

8.1 Financing the Planning Process

Funding a continuing planning process for urban stormwater runoff involves two distinct phases. Phase 1 is the initial planning effort that includes data collection, analysis, preparation of basic maps, and the variety of other activities that go into developing management strategies. Phase 2 is the continuing planning effort necessary to keep management strategies current in terms of development patterns in the region and emerging management approaches. Phase 2 is frequently the more difficult problem to cope with from the standpoint of funding. Transportation planning which was heavily financed by the federal government in the early 1960's for the initial planning phase did not receive much support as a continuing process. Section 208 Areawide Waste Treatment Management planning is intended to be a continuous planning process, with annual updating of the approved areawide plan; but in the absence of continued federal support it will be necessary for localities to pick up the added planning costs and this may prove to be a serious sticking point.

There are three basic approaches open to local government for funding a stormwater management planning process:

- Prepare stormwater plans as an integral part of the larger 208 areawide water quality management plan;
- Prepare stormwater plans in conjunction with other on-going city or county planning efforts; or
- Prepare stormwater plans as a separate, distinct city or county planning activity.

Funds will be needed initially for the range of activities involved in the development of urban runoff management strategies. These activities include review of existing information, data collection, delineation of physical methods, analysis of alternative physical methods, identification of implementation measures and institutional arrangements, and formulation and evaluation of alternative runoff management strategies. After the initial planning effort has been completed, funds will be needed for publication of the draft plan, informal public discussions, formal public hearings requiring legal notice and record, and revision and final preparation of an urban runoff management strategy. Following adoption of a management strategy, funds will be needed for implementation and enforcement (See section 6.2) and for the periodic review and revision of the approved plan. This periodic review and revision, when appropriate, is the essence of a continuing planning process.

Sources of funds for an initial planning effort will usually come either from federal and/or state grants, or from general funds. For example, urban runoff management planning would clearly be an appropriate activity for 208 Areawide Water Quality Planning Agencies funded under PL 92-500; another source of grant monies might be the HUD 701 Program. The local general fund is always a potential source of monies for planning, provided that responsible local officials can be persuaded to appropriate the funds. Other sources of funds, such as special assessments and full-cost recovery user charges are theoretically available, but as a practical matter they are not available to finance initial planning. However, the continuing planning process might be funded in this manner.

6.2 Financing the Management Process

Funding the implementation and enforcement of urban stormwater runoff strategies is also a multifaceted problem. Implementation activities may be undertaken by either the public or the private sector. Enforcement activities are usually carried out by public entities. Implementation activities include: monitoring quantity and quality of runoff; administering a permit procedure; holding public hearings; and installing and operating facilities for retaining, retarding, and/or treating runoff before discharge to receiving waters and similar activities. Enforcement activities include: surveillance of construction sites; inspections required to obtain operating permits; preparation and presentation of materials for enforcement actions; and similar activities.

There are five basic approaches available for funding implementation and enforcement activities related to urban stormwater management:

1. General Fund revenues
2. Permit and Licensing Fees
3. User Charges
4. Fines and Penalties
5. Grants

Rather than discuss these alternative funding approaches in the abstract, the rest of this chapter is devoted to consideration of their utility in meeting a series of specific local stormwater problems. The choice among alternatives, in each instance, will be evaluated in terms of revenue adequacy, social equity, economic efficiency, and administrative simplicity.

5.3 Financing Specific Preventive Approaches: Five Examples

The following examples have been selected to illustrate methods of financing various preventive approaches designed to overcome already identified stormwater problems. The examples illustrate a variety of financing methods, and as can readily be observed, these financing methods can be applied to a number of problems. The methods can be used singly or in combination with other methods to provide the needed financing.

Some approaches require substantial outlay of public (government) money while other approaches avoid the necessity of expending public funds. For example, a permit program shifts the cost directly to those who seek permits. Thus, financing specific approaches may be viewed as (1) identifying sources of funds to defray public expenditure or (2) identifying approaches which reduce or avoid the use of public funds and thrust the burden of costs, if any, on the private sector. In some instances neither the public sector nor private sector which is subject to the regulative impact of the selected approach may experience a reduction in value of its property, or a capital loss.

5.3.1 Development in an Aquifer Recharge Area

Problem: The quantity and quality of a water supply dependent upon an aquifer is endangered due to increased development in the aquifer recharge area.

Approaches:

1. Designate aquifer recharge areas as a critical environmental area; Public acquisition of title to the recharge area to maintain it in its natural state.

2. A public system to recycle stormwater from developed portions of the recharge area to the still undeveloped areas.

Needs for Financing:

1. Approach 1. Cost of purchasing the land comprising the recharge area.
2. Approach 2. Cost of land acquisition, if required, plus costs of contructing, maintaining, and operating the recycle system.

Sources of Financing:

1. Approach 1. The publicly owned water supplier could issue revenue bonds (long-term borrowing) to be retired from revenues of water users who are dependent upon the aquifer for their water supply. This could be an element in the charge system for water users.
2. Approach 2.
    a. Issuance of revenue bonds as set forth in approach 1.
    b. To the extent that owners in the developed portion are benefited by the stormwater drainage system, such owners could be assessed on a benefit basis to provide funds to retire bonds issued to provide capital.
    c. The costs of maintenance and operation of the recycle system could be financed by "user charges" on the benefited property owners in the drainage area (i.e., charges based on amount of runoff as computed by lot size, soil permeability, and existing improvements such as driveways and roofs), or more broadly through charges to all water users.

Evaluation:

These methods of financing can be manipulated to provide adequate funds since charges to users can be adjusted to assure the needed amount. It is fair in that those benefited--users of the water and those benefited by the storm sewer system--bear the costs. It is, however, somewhat rigid since it is capital intensive, and once the costs are incurred they must be repaid. The methods should be within the legal authority of local governments or water districts since this is not an unusual method of raising capital. It does require constant administration, but the administrative agency is most likely already in existence, and it could make the collection process part of that already established. While water bills would increase, the assurance of a water supply should enhance public acceptability.

5.3.2 Polluted Runoff in Developed Area

Problem: Existing and projected development in a drainage area is causing, and threatens to cause, increased stormwater runoff containing increased levels of contaminants.

Approaches:

1. Site planning which requires each major developer in the drainage area to provide for delaying runoff and removing contaminants.
2. Publicly owned and operated runoff retention and treatment facilities such as settling ponds adequate to handle the "first flush" during rainstorms and the water from periodic street and parking lot cleaning.
3. Comprehensive maintenance program, including litter pickup, street cleaning, catch basin cleaning, parking lot cleaning, etc.

Needs for Financing:

1. Approach 1. The primary costs to the public sector in this approach are planning and management (monitoring and enforcement). The major costs will be borne by the private sector in providing the facilities to delay runoff and to remove contaminants.
2. Approach 2. The principal costs in this approach are borne by the public and include: (a) land acquisition for retention and settling ponds, (b) construction of stormwater collection systems, (c) construction of retention and settling ponds, and (d) operation and maintenance of the entire system (including treatment, if necessary).
3. Approach 3. The principal costs will be borne by the public and include: (a) acquisition and maintenance of street cleaning equipment, and (b) labor and supplies.

Sources of Financing:

1. Approach 1. The public monies needed for planning and management are relatively small. As noted previously these may be paid from general revenues, assessments on benefited land owners, or license or permit fees, or a combination thereof. The private sector, which must bear the most significant share of the costs, can recover this by increasing the price of their land and/or improvements on the land when the land is sold.

2. Approach 2a. Long-term borrowing in the form of bond issues is the most likely source to supply funds for capital expenditures such as land acquisition and costs of construction. Typically, the context within which these types of needed capital investments arises is multi-jurisdictional in nature. These bonds could be repaid from assessments on benefited landowners--i.e., those within the drainage area sewered by the facilities. The assessment would be based on, or in proportion to, (1) amount of runoff from each parcel of land, or (2) area of land which is developed.

Approach 2b. The costs of maintenance and operation of the system could be financed by user charge on owners in area served. This user charge should be based on volume of runoff and contaminants, if any, in the runoff which need treatment. Volume can be calculated on size of lot and soil permeability. Contaminant-based charges can be based on use of land--parking lots, heavily fertilized areas, outdoor storage areas, etc.

3. Approach 3. The costs of equipment, if substantial, may be financed by long-term borrowing in the form of bond issues. More likely, however, this cost plus operational costs will come from the general fund.

Evaluation:

In the case of the first approach which places the heaviest costs directly on the private sector, those creating the problem--developers and those purchasing from developers--bear the cost. This approach may, however, not provide the economies of scale that may be gained with larger, publicly owned facilities (such economies of scale do not exist in all cases). It may, however, result in cooperation among private developers and in more innovative approaches to the problem since the private sector would be attempting to minimize costs. Costs to the public sector are greatly minimized.

In the second approach, in which the public sector incurs the initial expense, the placing of the ultimate burden on those creating the problem is fair. From the public sector point of view this method should provide an adequate source of revenue. To a certain extent, the adequacy is dependent upon the basis on which benefit assessments are calculated. As an example, if based on area and permitted intensity of development of each parcel, the owner pays on the basis of the benefit whether developed or not. If based on calculated runoff the cost of constructing the facilities based on projected development will be incurred, but development may not occur.

Both should be easy to administer and there should be no need for new legislation. By spreading the costs among those benefited, it should be politically feasible and socially acceptable.

The third approach (comprehensive maintenance) in which the public generally bears the cost is a fair one, and also one which promises adequate revenue possibilities. It also may serve multiple objectives, including public health, aesthetics, reduced unemployment. Finally it is attractive because these maintenance activities are traditional functions of municipal government, and can readily be redirected to water quality goals.

5.3.3 Polluted Runoff in Undeveloped Area

Problem: Projected development in a relatively undeveloped area will increase surface runoff and increase contaminants in receiving waters.

Approaches:

As a first step, determine and establish acceptable quantities of runoff. This in turn can be used to control the composition of the runoff indirectly, through local ordinances incorporating performance standards. Other means available to control development include:

1. Limit overall development and/or paved and roof surfaces in the area. As part of this approach, allocate development rights to each parcel based on size of the parcel. These should be recorded as part of the land records. This could result in a form of land use control for each parcel not based on density, but based on paved and roof surfaces.
2. Allow a market in the development rights, e.g., "transferable development rights" (TDR's) with public agencies overseeing the transfers and maintaining records of them.
3. Require maintenance of open or undeveloped areas, or require planned unit developments.
4. Acquire development rights so that the public may directly control and prevent their use.
5. Encourage "open space," forest/or agricultural preserves by substantially reduced real estate taxes and/or by credits against other state taxes for land maintained in accordance with preservation objectives.

Needs for Financing:

1. Approaches 1, 2, and 3--Public Sector.
In all three of these approaches, the primary need for public sector funds is in planning and management. Funding needs may be considerable, since establishing the "acceptable" runoff is technologically complex. The monitoring and enforcement aspects of management may be more expensive than usual if the governmental entity becomes involved in administering the market for TDR's.

2. Approach 4--Public Sector: Funds will be needed to purchase the TDR's.

3. Approach 5--Public Sector. While funds are not needed for out-of-pocket payments, there is a loss to the public sector in the form of reduced tax income. Although difficult to measure, this lost tax income should be partially offset by a reduced need for public funds to meet water quality standards in the receiving waters.

4. Approaches 1, 2, and 3--Private Sector
The private sector may experience increased development costs although "cluster developments" usually result in lower development costs per dwelling unit for roads and utilities. As in the case of restrictions on development the private sector bears the loss of profits that could have been gained through more extensive development.

5. Approach 4--Private Sector. There is no need for funds and theoretically no economic loss, since the public sector pays for TDR's that it acquires.

6. Approach 5--Private Sector. There is no need for outlay of private funds, and the tax credits offset any economic loss.

Sources of Financing:

1. Approaches 1, 2, and 3--Public Sector. The planning area is one in which grants may be available. The Federal Water Pollution Control Act Amendments of 1972 provide planning funds for states to determine water quality levels for receiving waters (e.g. §106 and §303(e)). Section 208 of the Act providing for areawide planning is also a source, since areawide planning must include identification and control of non-point sources of pollution such as surface runoff.

If the public sector becomes involved in administering the transfer of TDR's, a transfer fee could be charged for such administrative service.

2. Approach 4--Public Sector. Funds to purchase TDR's could come from a bond issue to be repaid from assessments on all properties in the drainage area.

3. Approach 5--Public Sector. The reduced tax income would have to be offset by tax income from other sources such as an increase in taxation on the developed property in the drainage area.

4. Approaches 1, 2, and 3--Private Sector. As in the case of other restrictions and constraints on development, there is an economic loss of possible profits resulting from more intensive development. These can be recovered to the extent that the market will bear increased costs for the land.

5. Approaches 4 and 5--Private Sector. No need for private funds except to the extent that taxes on other property owners would have to be increased to provide funds or offset lost income tax revenues.

Evaluation:

Since the need for public sector funds is small, revenue adequacy would not appear to be a problem. The use of planning already conducted or being conducted pursuant to the Federal Water Pollution Control Act would be economical and would enhance coordination. The fee charged for facilitating and administering the transfer of TDR's would offset the costs.

By allocating TDR's to each parcel, landowners could transfer these so as to facilitate development but within the overall constraint of allowable runoff. This provides flexibility and the opportunity for economical development while maintaining open spaces. This also provides a mechanism for government to acquire TDR's thus lessening the burden on those private owners whose land is restricted. This would avoid a possible "taking" issue. Such an approach may, however, require new legislation, and it must be coordinated with other land use control objectives--traffic, schools, providing industrial zones, etc. The tax incentive in the "preserve" approach may require new legislation in order to avoid legal problems such as a requirement that all property be taxed on a uniform basis. To the extent that all of these approaches are somewhat novel--not conceptually, but in application--there will be an increased administrative burden. Until the approach is implemented and experience gained in its application, it will take more time and staff to administer as compared to more familiar approaches.

5.3.4 Development Adjacent to a Stream

Problem: In an area adjacent to a stream existing development will cause (1) stream bank erosion, and (2) sedimentation and pollution from surface runoff into the,stream.

Approaches:

1. Designate the areas adjacent to the stream as a "critical environmental area," and acquire conservation easements (i.e. limiting development or maintaining area in its natural state) from property owners along the stream by purchase or by requiring dedication of easement as a prerequisite to development.
2. Site planning by land use controls which restrict development along the stream. This could be coordinated with flood plain land use regulations.
3. On-site construction activity controls which require maintenance of vegetative cover and construction methods that prevent erosion and runoff.
4. "User charge" or "contributor charge" based on the Universal Soil Loss Equation--i.e. a charge levied on property owners in the watershed based on their contribution to the sedimentation problem. The elements of the soil loss equation include soil type, slope, ground cover, etc.

Needs for Financing:

1. Approach 1. Acquiring conservation easements directly means outlay of public funds. Alternatively, the locality could require dedication of conservation easements by owners and developers before allowing development in the area, resulting in no costs to the public sector.
2. Approach 2. The principal costs to the public sector in this approach are planning and management (monitoring and enforcement). Costs to the private sector are not "out-of-pocket" costs but rather lost opportunies for development

3. Approach 3. The primary costs to the public sector in this approach are planning and management (monitoring and enforcement). Costs to the private sector are (1) planting and/or maintenance of required vegetative cover, and (2) any increase in construction costs necessitated by compliance with required construction methods, plus maintenance costs if any. If the private sector fails to perform its maintenance requirements, the public sector as part of its enforcement function must step in and perform.

4. Approach 4. The costs to the public sector are for determining and collecting the charge. Costs to the private sector, are, of course, the "user" or "contributor" charge.

Sources of Financing:

1. Approach 1. Alternative 1. The costs of conservation easements should be substantially less than acquiring the fee (entire) title to the land adjacent to the stream. This cost is usually determined by the difference in the value of the land before and after imposition of the easement. Funds could come from general revenues or from assessments on all lands within the drainage area. All such lands tend to benefit since the conservation easement may allow them to make more intensive use of their lands in that the vegetative cover of the land in its natural state would retard surface drainage into the stream. Alternative 2. The cost to the public sector is negligible since dedication of the easement is made as a prerequisite to development. The cost to the private sector is recovered by increasing the sale price of the developed lands. A problem could arise if the landowner does not own sufficient land to develop after dedicating the conservation easement.

2. Approach 2. The public monies needed for planning and management are comparatively small. These may be paid from general revenues or assessments on benefited landowners--i.e. those within the drainage area. The private sector, while not bearing any out-of-pocket expenses, suffers the loss of opportunities to develop. This may be recouped by an increase in sale price on the balance of the land which is contrary to the public good-- i.e., causes harm to the public waters in the stream.

3. Approach 3. The public monies needed are only for planning and management (monitoring and enforcement). The costs to the private sector are recovered in increased costs to purchasers of the developed lands. To the extent that the public sector must step in and perform maintenance, such costs can be assessed directly against the benefited parcel--i.e., the parcel on which the maintenance is performed.
4. Approach 4. Public monies are needed only for determining and collecting the charges. The charges can be collected along with other property taxes which minimizes the administrative burden. The private sector will pass the costs along in the same manner as other property taxes or assessments.

Evaluation:

To the extent that public funds are used, the public generally benefits by cleaner waters in the stream. Thus, use of general revenues is fair since the public generally is benefited by the imposition of the conservation easement on a few property owners. To the extent that the private sector bears the costs, these can be passed on to purchasers of the developed portions of the land. A definite problem arises, however, if the servient landowner--i.e., the owner whose property is subjected to the conservation easement--does not own sufficient land for development outside the area subject to the easement. In considering Approach 2, there is the same impact on the private sector as in the case of the dedication of the conservation easement. In the case of Approach 3, the increased costs are passed on to purchasers of the land. In the case of costs to be borne by the private sector, these "financing methods" appear fair in that those causing the problem bear the cost.

There is little or no problem as to adequacy of funds from the public sector if the funds are appropriated when the governmental entity decides to use the conservation easement approach. In the case of the private sector, the additional costs may be passed along if the market conditions allow. If not, then development will be curtailed.

The exacting of a conservation easement and the imposition of land use controls under the "police" powers of the government always run the risk of being held a "taking" as discussed previously.

5.3.5 Wetland Development

Problem: Wetlands, which provide breeding grounds for aquatic life and water fowl, are endangered by development in the wetlands themselves and in adjacent areas. Dredge and fill operations in the wetlands and runoff of fertilizers and pesticides from nearby developed areas are the principal threats.

Approaches:

1. Designation of wetlands as a "critical environmental area." Alternative 1a would be to limit development in wetlands by restricting dredge and fill operations, in conjunction with laws and regulations applicable to navigable waters (e.g. Rivers and Harbors Act of 1899). Alternative 1b would be public acquisition of conservation easements to limit development in the wetlands or keep them in their natural state.
2. Regulate use of pesticides and fertilizers in the drainage area that affects the wetlands. Such regulations include limiting types of fertilizers and pesticides used and licensing applicators to assure control of methods of application.

Needs for Financing:

1. Approach 1a. The principal costs to the public sector in this approach are planning and management (monitoring and enforcement). The costs to the private sector are not out-of-pocket, but are the loss of speculative profits based on development of the wetlands.
2. Approach 1b. The cost to the public sector is that of acquiring conservation easements in the wetlands area. The private sector bears no cost since owners are compensated for any "loss" in value by imposition of the conservation easement.
3. Approach 2. As compared with the customary planning and management costs, the costs of monitoring and enforcement may be considerably higher. This results from the necessity to license and constantly monitor the distribution and application of fertilizers and pesticides.

Sources of Financing:

1. Approach 1a. Federal planning grants under such laws as the Coastal Zone Management Act are a possible source of planning funds. Other sources include the general fund and, perhaps, financing on an intergovernmental cooperation basis. From the private sector's point of view loss of speculative profits may be offset by increased or enhanced value of adjacent lands. The wetlands could also be used in computing density requirements for non-wetlands areas. Thus, more intense development may take place in the non-wetlands area to help offset the loss of speculative profits.

2. Approach 1b. The costs of conservation easements should not be large since the wetlands are not ready for development without extensive and expensive dredge and fill operations. Thus, the difference in the fair market value of the wetlands in its natural state and the wetlands burdened with the conservation easement is small. Such costs could come from general revenues of the political subdivisions having jurisdiction of the wetlands. A wetlands protection district might be formed with authority to accept and/or raise funds to acquire such conservation easements. To the extent that commercial enterprises, or even sports groups, benefit from the maintenance of the breeding grounds, license or permit fees could be assessed to provide funds.

3. Approach 2. The additional costs of monitoring and enforcing the regulatory program could be offset by license and permit fees imposed on distributors and applicators of fertilizers and pesticides. To the extent that the public sector uses such fertilizers and pesticides--e.g. highway department, parks and public recreation, public health, etc.--monitoring and enforcement should be less expensive since such government agencies could "police" themselves.

Evaluation:

To the extent that development in wetlands is quite expensive, the value of the wetlands in its natural state is low compared with non-wetlands development areas and restricting its use does not place a great burden on the private owners. When conservation easements are acquired by use of public funds, fairness is assured to all concerned--both to the public and private sectors. The source of funds from general revenues is, however, subject to appropriations and runs this risk of uncertainty. The licensing of distributors and applicators may require enabling legislation or at least promulgation of regulations by environmental or coastal zone management agencies.

REFERENCES

1. These two principles of public finance have been stated by Musgrave. See Richard A. Musgrave, The Theory of Public Finance (New York: McGraw-Hill Co., 1959).

   In practice, the ability to pay a levy is usually defined in terms of income. This principal is not generally considered in an analysis of sewerage service charges because these charges are rarely, if ever, related to an individual's ability to pay them.

2. As a measure of value this test is rather crude because total revenues are compared with total costs and no analyses are made at the margin.

3. Connection fees and minimum charges both meet this criterion. Total costs would be equal to either marginal cost of service plus a connection fee or a minimum charge computed by dividing total costs by population served.

6.0 INSTITUTIONAL ARRANGEMENTS

The success of stormwater management depends upon its implementation. Master plans can be created, technical solutions proposed, and legal obstacles surmounted, but eventually officials responsible for the control of stormwater runoff must address the crucial question: what institutional arrangements will be required to carry out an effective stormwater management program?

Previous chapters have dealt with the elements of a stormwater program and these elements fall within a suggested approach--a preventive one. The preventive approach of best management practices requires the simultaneous and coordinated application of control measures. Its simpler alternative, end-of-pipe treatment is too expensive, calling for astronomical expenditures. If stormwater programs are thus constrained by the technical measures available, they are equally limited by the complexity of the governmental system which is responsible for the implementation of programs. Because radical political reorganization around the watershed will most probably not occur, local government must look to informal mechanisms and existing institutions. How existing governing bodies can best be adapted to the implementation of stormwater runoff control, is, then, the subject of this chapter.

6.1 Existing Patterns of Control for Stormwater Management

The control of stormwater is vested in several layers of government and, in addition, is related to other goals. Depending on the jurisdiction, the State may assume a more important role than other governmental units such as counties, municipalities, or special purpose districts. The function of stormwater control also encompasses other objectives: erosion control, flood control, transportation planning, and solid waste management, for instance. Again, the spectrum of concommitant goals creates the necessity of coordination across functions with responsible agencies which may, in turn, have local, regional, or statewide authority.

Stormwater pollution respects no political boundary. As a result, the institutional coordination required for storm water control directly involves many different levels of government.

State Agencies

In each of the fifty States, at least one statewide agency has the primary responsibility for water quality control within the State. These agencies will be deeply enmeshed in stormwater runoff problems, for as the Environmental Protection Agency *Water Quality Strategy Paper* indicates: "Control strategies will be developed by designated Areawide planning agencies and by States. For both, section 208 provides the principal authority for addressing nonpoint sources."[1] For this reason, State water pollution control Authorities will continue to have a direct hand in the implementation of stormwater management programs.

Within a number of States,[2] however, the responsibility for water pollution control has been retained by the State public health agency; such an arrangement is probably not conducive to vigorous and comprehensive stormwater control efforts, if only because these health agencies will be occupied with many other quite different concerns. The "mission" orientation of public health agencies may dampen efforts to analyze stormwater problems where no direct and incontrovertible threat to human life is present, such as the presence of pathogens.

State involvement in stormwater control also occurs because agencies of nearly forty percent of the States[3] may carry out flood control projects by building levees, dams and so on. The authority to prevent the construction of flood control works is another source of State influence. In several States, the plans of all flood control projects must be approved by a designated State agency, thus allowing an effective veto over the actions of local agencies in this area.

Soil and erosion control, a goal closely related to stormwater control, has come under the influence of Statewide direction in many areas, especially through statutes which create soil conservation districts[4]. Most of these soil conservation district statutes grew out of the Dust Bowl disasters of the 1930's. Recently, they have often been amended to reflect current concerns over the water pollution caused by sediment transport. The use of the veto power against local efforts which do not conform to a unified soil erosion and sedimentation control program is a common mechanism for statewide direction. For example, Michigan provides for local control; yet "an ordinance which is not approved by the commission as conforming to the minimal requirements of this act and the rules shall have no force or effect."[5]

The objectives of stormwater control thus come under the authority of many existing State agencies. For example, because transportation residuals so directly affect the loading intensity of streets and because highway construction standards should conform to existing erosion control laws, State agencies responsible for highway planning and design may also become involved. Other agencies concerned with solid waste disposal should be consulted, for many of the technical measures employed will generate the need for solid waste disposal.

This is a cursory overview of State involvement in stormwater control. The plethora of related agency involvement causes problems. For example, Michigan's Bureau of Outdoor Recreation prepared an environmental impact statement on a proposal to create a 3500 acre recreation facility, which was to include a 618 acre impoundment. It was not a State agency which challenged the water quality impacts of the proposal. Rather, a local body, the Huron River Watershed Council, reviewed the plan and alerted the State to many overlooked detrimental effects of the impoundment.[6] Thus, vesting authority for runoff control at the State level should not be seen necessarily as a desirable and automatic choice. Local government plays a decisive role in this area.

Cities and Counties

The drainage of a city in the interest of the public health and welfare is one of the most important purposes for which the police power can be exercised. The power vested in municipal authorities to construct sewers and drains is not exhausted when once exercised, but is a continuing power that may be exercised to supply needed facilities at any time. This power to construct and maintain a drainage system is conferred by charter or statute.

Many of the water quality problems which result from stormwater runoff can be traced to this history of local control for drainage. In the past, it was thought that the overriding purpose of a stormwater drainage system should be fast removal and efficient disposal. The management of these systems was seen as an engineering problem divorced from other urban systems and activities. In addition, sewer design by the

Rational Method considered neither the timing of the flow nor the quality of the flow. As a result, little thought was given to designs employing detention and storage. Although the environmental damage caused by stormwater runoff is now recognized, a hold-over from this past remains--the view of stormwater control as a local problem with an engineering solution.

Nevertheless, the authority to construct and maintain sewer systems remains critical to the future of stormwater management. Because urban growth[7] tends to follow along the patterns of sewer construction, this power--if directed through careful planning--can accomplish much toward the retardation of runoff velocities. Much therefore depends upon the wise use of local police powers.

Land use control is another area traditionally within the purview of local government. Zoning, being an exercise of the police power which resides in the several States, is a form of land use control usually delegated to local governments through enabling legislature. This means of regulation provides a cornerstone to the preventive approach, and is more fully dealt with in other chapters of this manual. As it affects a related goal, that of transportation planning, the zoning requirements of the many local planning boards can do much toward the reduction of pollutant loadings on street surfaces. Planning boards and zoning departments, apart from their many powers, thus control a major contributor to runoff pollution, which is the traffic-related residuals. This control is applied through regulations made to lessen traffic congestion as well as through off-street parking requirements.

Therefore, in the pattern of institutional arrangements for stormwater control, local governments play a fundamental role. Planning boards shape the programs which seek to achieve many of the objectives related to stormwater runoff management. Departments of public works determine the success of the technical solutions suggested in the preventive approach--street sweeping, sewer flushing, and catch basin cleaning to name a few.

Counties share with cities many features and, of course, have regulatory powers which are supplemental to those of the State. In many instances counties create pollution control offices which play a part in runoff control. The Metropolitan Dade County Pollution Control ordinance[8] which creates such an office is an example of the assertion of a county's role in runoff management. Although not specifically enacted for that purpose the ordinance, for instance, prohibits the discharge of wastes into storm sewer systems. Erosion control may also be exercised by counties as evidenced by the Environmental Policy and Land Development Standards ordinance of Dekalb County Georgia.[9]

Special Districts

Special districts are the most diverse and least understood group of local governments in the Nation. They are limited purpose governmental units which exist as separate corporate entities and which have substantial fiscal and administrative independence from general purpose local governments. Many perform functions related to stormwater control. Their prevalence is illustrated by the following table.

Figure 6.1

Prevalence of Special Districts in the U.S.

	Northeast	North Central	South	West
Single Function				
Drainage	-	1,152	721	319
Flood Control	5	384	264	131
Irrigation, Water Conservation	1	131	102	737
Soil Conservation	72	881	1,022	586
Other				
Parks & Recreation	44	484	48	174
Sewerage	539	326	124	422
Multiple Function				
Sewerage and Water Supply	174	86	231	198
Natural Resources and Water Supply	-	11	20	46

Source: Census of Governments

As Figure 6.1 indicates, the prevalence of special districts varies regionally. While the South tends toward the frequent use of these instruments for a wide range of stormwater-related functions, the Northeast on the other hand does not. Overall, the primary reasons for their creation are: (1) fiscal self-sufficiency, (2) emphasis on technical specialization, (3) efficiency, (4) geographic flexibility.[10] Special purpose districts have only those powers that are expressly granted to them or are necessary to carry out the conferred powers. Their creation will generally be invalid only where requirements in enabling legislation are lacking.[11]

In their relation to stormwater management special districts have few powers in the area of pollution control, but in such areas as drainage and flood control they are by far the most important governmental body. In addition, soil conservation districts are a dominant method for erosion control; the creation of such districts is authorized in forty-six states. Such districts are empowered to develop comprehensive plans where earth disturbance occurs.

Special purpose districts do not offer a general solution to the fundamental dilemma at hand. An instance of an acute jurisdictional morass existed in one county which included within its borders one county-wide drain board, one county-wide park board, three separate water management districts, two soil conservation districts and most of one irrigation district. To make matters even worse, that irrigation district extended into two other counties so that coordination between the several districts would require contact with two drain boards, three park boards, four water management districts, and four soil conservation districts. This chaos is not atypical. One survey indicated that there were 143 counties across the nation which contained over 25 special districts within their boundaries.

As an intergovernmental solution, special districts have several failings. First, there is commonly a duplication of roles to be fulfilled by different districts. Second, there does not often exist a mechanism for statewide supervision that would ensure adequate coordination of the districts' plural and separate efforts to meet their overlapping responsibilities. Finally, the variations possible in jurisdictional boundaries make cooperation even more difficult.

The Intergovernmental Tangle Facing Stormwater Control

In light of these existing patterns of control, one implication is clear: the control of stormwater programs is fragmented between levels of government and across functional responsibilities. State agencies, local departments, and special districts confront each other with different interests yet possess coordinate powers. One director of a western Urban Drainage and Flood Control District indicated how difficult it was to embark upon a program of water quality monitoring, owing to the functional distinctions between flood control and water quality control. Even though the district was the appropriate institution to conduct such a survey, the impediment lay in the difficulty of a single purpose agency to control a multi-faceted problem. The preventive approach to stormwater management must confront and successfully deal with this reality of fragmented responsibility.

Because the preventive approach involves regulatory as well as physical controls, the tendency toward institutional conflicts remains ever-present. Where conflict does not openly arise, responsible agencies may well work at cross-purposes. Public works departments may not perform maintenance operations (street sweeping, catch basin cleaning and the like) in coordination with the programs of transportation planning bodies or other related agencies.

Essentially, the institutional problems remain intergovernmental ones given the balkanized arrangements of functions in our system of government. An areawide approach to the problem such as that envisioned by Section 208 of the Federal Water Pollution Control Act Amendments of 1972 attempts to ameliorate the dilemma, but the problem persists. Other measures, such as A-95 review, seek to avoid duplication of efforts where federally funded programs are involved, yet conflict continues.

6.2 Toward Better Institutional Arrangements for Stormwater Management

Bertrand de Jouvenel stated the problem succinctly at the 1967 Water for Peace Conference, "All our institutions are aimed at regulating relations between men, practically none at regulating the relations between Man and Nature."[12] Although this state of affairs has improved considerably with the passage of the Federal Water Pollution Control Act Amendments of 1972 and the strengthening of state water quality agencies, the difficulty remains in bending institutions to a purpose they are unaccustomed to serve and in directing separate efforts toward common ends.

If the nature of our institutions represents a problem, it is only part of the dilemma; the nature of the preventive approach also leads to complexity in the number and type of institutions involved in a control program. The preventive approach to stormwater pollution is, by and large, an indirect one. The more direct approach would be to capture the sewer discharge through interceptors and then to treat the effluent at a plant designed for this purpose. Although direct, this approach would be very costly. More importantly, it addresses itself to the results, not the causes, of the pollution. When the causes of pollution become the focus, then the control of runoff becomes one among a number of goals of a control program. The sources of runoff pollution are also sources of other problems, and control techniques useful for pollution abatement are also useful for other functions. For example, the debris-laden curb is a source of pollution as well as a blight on the cleanliness of the city. Clogged drainage ways resulting from sediment carried away from construction sites also increase the potential for flooding problems. Trees serve to hold sediment in place in addition to offering pleasing landscapes for the community. Detention facilities may be designed to ameliorate flooding as well as to allow a sizeable reduction of pollution through the settling out of particulate matter.

While this increased degree of complexity can be a disadvantage, it can also lead to certain important benefits: (1) it is more equitable to shift the burden of control onto those areas and individuals which cause the problem; and (2) it is more acceptable to the electorate that tax dollars should be spent on programs which contain several legitimate goals instead of attempting to justify expenditures upon the grounds of stormwater control alone. Thus, even with the added institutional complexity, a comprehensive approach to the causes of stormwater pollution may make sense on grounds of both equity and practicality.

At least four major factors should be considered when selecting among alternative approaches to stormwater pollution control. The allocation of responsibilities and authority for stormwater management among agencies ought to take into account:

- the nature of the particular stormwater problem;
- the nature of the controls employed and the coordination needed to carry them out;

- the maintenance requirements of the program which ensure the effectiveness of the controls;
- the implementation needs of a control program.

Each of these factors highlights a different aspect of the institutional arrangements necessary to carry out a stormwater control program. First, the nature of the problem itself enables the planning agency to identify those governments and agencies which hold jurisdiction over particular sources of pollution. Second, the type of cooperation desired from these responsible agencies depends in large part upon what controls appear promising, since many of these controls necessitate different forms of coordination. Third, whatever the control program selected, its continued effectiveness will entail maintenance of the physical techniques employed; thus, planning or permitting systems must be coordinated with inspection and enforcement agencies. Finally, an overriding concern is to consider the means required to implement the program to make it understandable and acceptable not only to the agencies which will do the regulating, but also those interests being regulated and the public-at-large.

The Nature of the Particular Stormwater Problem

The nature of the stormwater runoff problem in a particular local area influences the institutional arrangements appropriate for its control. That such an influence is critical to the planning agency's efforts may be demonstrated from three perspectives: (1) drainage patterns; (2) pollutant constituents; (3) land use.

Some areas, for example, are fortunate in that their drainage patterns conform to political boundaries. An example of this situation is Dekalb County, Georgia. There the geography is such that almost all of the lands constituting the drainage basins of the streams within the County lie within the County's borders. Consequently, runoff problems created in the County can be solved by the County; runoff control is essentially a local problem. However in most instances, because drainage problems extend to the watershed and because the watershed does not often conform to political boundaries, interlocal cooperation will be necessary where stormwater runoff endangers receiving waters. If a management program is to succeed, it must involve those governments responsible for upland areas which pass the flow of stormwater unrestricted into the lowlands. For instance, the

Chicago Metropolitan Area suffered from this predicament, as a committee report of the Metropolitan Sanitary District indicates:

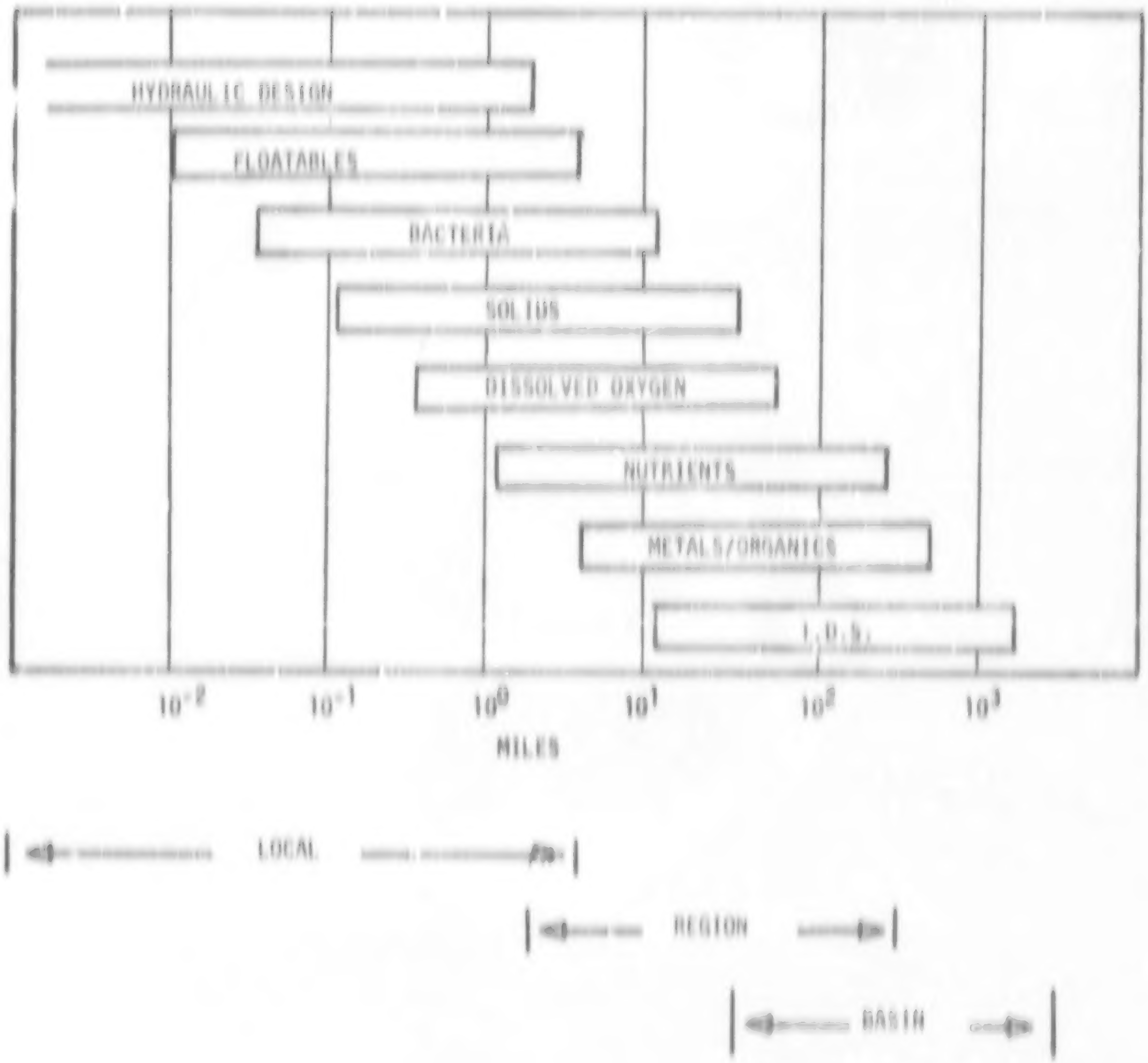
> The region-wide or basin-wide flooding problems within the Chicago Metropolitan Area result from a number of causes, for example, unrestricted flow from upstream areas outside of the jurisdiction of the Metropolitan Sanitary District...The solution to these basin-wide and region-wide flooding problems cannot be accomplished through the sewer permit ordinance, but must be performed by the responsible governmental bodies.
>
> It is not the intent of the Sub-Committee that numerous small puddles and ponds be constructed throughout the Metropolitan Area. Such scattered ponds may create nuisance and possible health hazard and fail to provide flood protection if not adequately maintained. Rather, the purpose of the recommended amendment to the Sewer Permit Ordinance is to encourage the development of well maintained landscaped lakes to act jointly as detention reservoirs and recreation facilities or aesthetic focal points in new village parks, either in incorporated or unincorporated areas...
>
> The Sub-Committee believes that the Federal, State, County, Metropolitan Sanitary District and other local agencies, should work together to provide overall planning, scheduling and funding for the large drainage basin projects...[1]

As a matter of equity, the reverse should also hold true: that a locality should not ignore the problem if it is in the fortunate position of being able to pass its problems downstream.

Although the drainage characteristics of an area are an important basis for identifying and involving the appropriate agencies of government in an effective control program, they are still only one consideration. Another is the characteristic of the runoff pollution's constitutents. Figure 6.2 indicates how the various constitutents of stormwater pollution (during one event) vary with respect to distance. From a glance, it can be seen that most pollutants are carried far and endanger the receiving waters beyond local boundaries. For this reason, intergovernmental coordination will be required in many cases. Figure 6.3 describes how stormwater constitutents vary in their persistance over time. Heavy metals, for example, are regional in scope and long-lived. In contrast, bacteria and viruses from a storm may not extend beyond local waters,

Figure 6.1

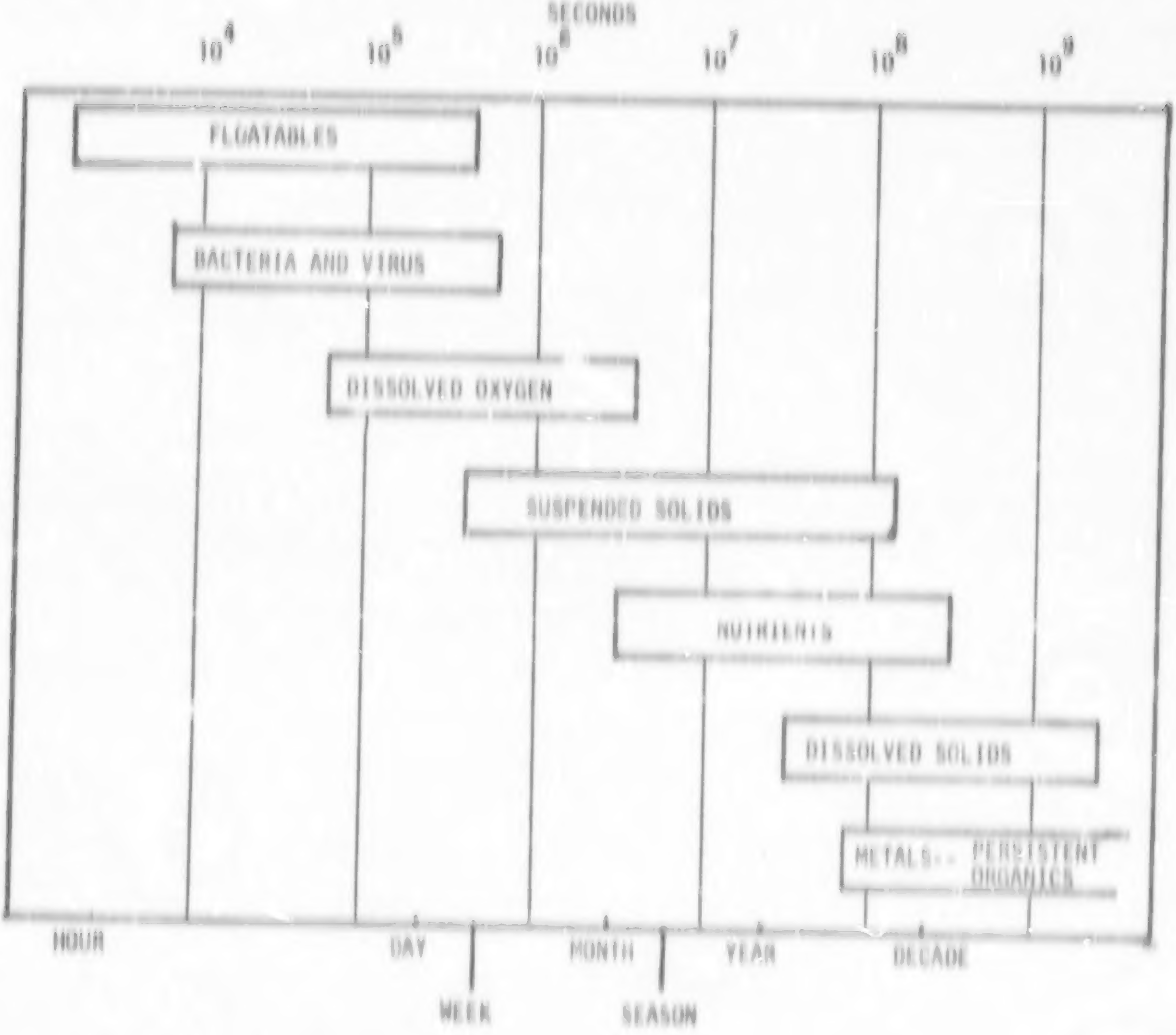
Stormwater Constituents and Their Effective Distance



SOURCE: Eugene Driscoll, "Instream Impacts of Urban Runoff," a paper delivered at the Urban Stormwater Management Seminar, Atlanta, Georgia, November 4-6, 1975

Figure 6.1

Stormwater Constituents and Their Persistence



SOURCE: Eugene Driscoll, "Instream Impacts of Urban Runoff," a paper delivered at the Urban Stormwater Management Seminar, Atlanta, Georgia, November 4-6, 1975 nor over a week's time. Some constitutents and their sources may transcend the abilities of any one community to implement control. A common example would be the lead compounds resulting from car emissions. No one could reasonably expect to achieve abatement of these compounds in runoff through local prohibition; the severity and extent of this problem has required federal regulation, and for reasons other than runoff control. Other constituents, such as the nutrients which cause eutrophication, may also require the action of superior authority, whether by the state or federal government.

In these cases where the runoff problem is clearly beyond the power of the affected localities to control, the appropriate course of action may be to petition the state government. An example is the Recommended Resolution for Regulation of Storm Drainage which Affects Separate Sewered and Unsewered Areas adopted by the Metropolitan District of Greater Chicago:

> Therefore, be it resolved, that the President of the Metropolitan Sanitary District of Greater Chicago hereby petitions the Governor of the State of Illinois to direct the appropriate department of the State of Illinois to:
>
> (1) Establish a flood control program for the State of Illinois based on the principle of retaining storm water runoff at or near its source, and
>
> (2) Regulate and control storm flow which pass from one county to another within the State of Illinois by establishing maximum flows at the county lines...[14]

It should not be concluded that runoff pollution is always beyond the scope of local government to influence and reduce and that local government lies helpless until superior authority acts. On the contrary, the individual community will be the linch-pin of any successful program of abatement when areawide cooperation comes about.

In addition to those natural features which affect the specific runoff problem, there are man-induced considerations--e.g., patterns of growth, the design of the sewer system, the traffic patterns of an area--which determine the total loadings of stormwater runoff in large measure. These elements of the problem, however, have always remained within the purview of local land use controls. Cities and counties through their police powers greatly influence pollutant loadings in stormwater runoff (See the discussion in Chapter 5).

The Nature of the Controls Employed and the Coordination Needed to Carry Them Out

Institutions having different authorities and functions are likely to become part of any areawide stormwater management plan. Once the cooperation of these organizations is gained, the type of coordination desired from them depends on the nature of the solutions which appear promising.

How does the nature of the control program affect the type of coordination necessary? Differing degrees of cooperation may be called for. To provide an example, let us assume that two communities adjoin and that a transportation network covers the locales evenly. Furthermore, the assumption might be made that the loading of the street runoff degrades the quality of the receiving water. In this case, if it is determined that an area containing multiple jurisdictions would benefit from street sweeping, then the type of coordination needed may be an inter-local contractual agreement which would share the capital investment in sweeping equipment and the maintenance costs for its operation. In this example, the nature of the problem dictates a concerted effort from two communities and the solution--street sweeping--requires the close and continued cooperation of the communities' public works departments. The coordination would involve scheduling of sweeper routes to achieve the maximum pollutant reduction, for if each department acted independently the effectiveness of the combined program could be drastically reduced and the additional expenditures wasted.

If an area experiencing rapid urban growth staddles jurisdictions and sediment constitutes a major difficulty, then the appropriate measure may instead be the simultaneous adoption by ordinance of performance standards for developers. To do so could involve the independent implementation by several jurisdictions of similar ordinances enacted with common objectives. Once these objectives are agreed upon by the affected governments, the operation of the program could proceed quite independently in each jurisdiction. This result was achieved in several counties surrounding Atlanta, Georgia. Dekalb County passed such an ordinance establishing performance standards for runoff from development, and as a result the bordering counties of Clayton and Gwinett have since adopted similar regulations. These counties evidence common problems. Since two of the six major drainage basins in Clayton County, Georgia, originate in Fulton and Dekalb counties the passage of similar ordinances functioned as a form of cooperative agreement to control a common problem. The counties, however, have jurisdiction only over unincorporated areas. Incorporated areas fall within the purview of municipal Public Works departments. To achieve systematic control over sediment delivered to the area's rivers has required that cities rely on regulations concerning the grading of land. In this manner, ordinances enacted by the counties and the cities in the Metropolitan Atlanta Area have, by and large, been successful in controlling stromwater pollution from sediment. This coordinated program evolved informally more by example than design. A smoother path may be found if the objectives desired from coordination are clearly stated at the outset, before independent programs are launched.

Runoff pollution problems are rarely simple, and even if one type of pollution predominantes, such as erosion and sediment runoff, many agencies may become involved. The State's highway department may be a contributor to runoff pollution through initial construction activities and subsequent highway runoff, in addition to private developers. From another perspective, no one stormwater management technique can be applied without regard for its unavoidable interdependence with other techniques. For instance, a comprehensive catch basin cleaning program cannot be designed without due consideration for the schedule of street sweeping activities, because the sweeper reduces the load available for entry into the catch basin. Where street sweeping is frequent, catch basin cleaning may be an infrequent need. Therefore when organisational responsibility for the two techniques is split between different agencies or departments, coordinated planning is necessary to ensure the maximum efficiency of an overall control program. This coordination should not end with the initial formulation of plans, but continue on a frequent basis as the program in implemented.

Once the nature of the problem and its sources have been assessed, the cooperation of those governments holding jurisdiction over elements of the problem must be gained. In some cases close cooperation may be required, but this is not always so since looser and more informal mechanisms may suffice. Part and parcel of this cooperation must be the identification and involvement of all those agencies which will be required to achieve the goals established for the control program. When methods of abatement are adopted for reasons including but extending beyond water quality, coordination may become an extremely intricate process involving many different organizations and interests.

The Maintenance Requirements of the Program Which Ensure the Effectiveness of the Controls

It is not sufficient that planning activities cease with the initiation of a preferred stormwater management program. Adequate means to ensure the continuation of the controls must be provided, otherwise the controls may become ineffective or even exacerbate runoff pollution.

The need to maintain the controls provided for stormwater runoff may create additional coordination problems. For example, while the authority to require on-site detention of runoff may be granted by statute to one entity, such as a soil conservation district, the statute may not vest enforcement or maintenance in the same agency. Similarly, the approval of development plans may rest with a special purpose district, whereas inspection of sites for noncompliance may remain with a department of the county government. Another typical arrangement is that maintenance may be left to the property owner. A description of Fairfax County's (Virginia) experience is instructive for the types of problems that can arise:

> County personnel feel that the major problem with their erosion and sediment control program is the inspection. Most of the inspection is done "after the fact" when little can be done. In addition, utility inspectors are used as inspectors for erosion and sediment control and usually lack the experience necessary for effective inspection within this area. Twice a year the County Development Department does give an erosion and sediment control refresher course to its inspectors in an effort to correct this situation and provide interaction between the Plan Review Section and the Inspection Department.

Where possible the planning agency should develop means to ensure that the authority to inspect is clearly provided and that this responsibility be carried out by qualified personnel. The allocation of responsibility for stormwater runoff management should include consideration of the inspection function as part of any existing or proposed runoff ordinance.

The risk of inadequate inspection is that runoff control measure will not be carried out or that they will be inoperative or ineffective during the construction period. A related aspect of the inspection problem is the involvement of the design engineer which can supplement local government inspection while not replacing it. In some cases, the consulting engineer hired to design the system does just that, he designs the drainage system and never sees the project again. Another engineer, usually employed by the developer, signs the as-built drawings. Especially in the control of erosion and sedimentation, when the construction phase is very important, some sort of continued inspection by the design consultant might be needed.

The necessary maintenance of the physical devices which become part of the runoff control program is closely allied with the inspection system. In some areas of the country, maintenance bonding is required of the developer. The ultimate success of any system of controls will depend on inspection and maintenance, but to achieve this success the planning agency must solicit the interest and awareness of the developer and of the public-at-large.

Implementation Needs of the Program

Many well conceived plans are currently collecting dust on agency shelves. In the planning process the nature of the runoff problem may be accurately conceptualized, coordination plans developed; maintenance requirements passed into law, and still the plan may not be implemented in the absence of a concerted effort to educate those who will bear the brunt of regulation, as well as the public at large. The principal obstacle to implementation stems from an indifferent attitude toward precious environmental resources and ignorance of the significant threats posed by runoff pollution. This attitude persists and requires much effort to change it. Education may do much to elicit a willingness to act.

For example, when Dekalb County passed its runoff control ordinance, the contractors and developers reportedly accepted the restrictions as outlined in the ordinance and very few problems resulted. One reason for this lack of problems could be that the Drainage Department conducted a series of workshops in which the drainage ordinance was explained and where the contractors and developers had the opportunity to ask questions concerning the application of the ordinance

Another approach is to create "blue ribbon" committees, such as was done by the Metropolitan Sanitary District in Chicago. This committee was composed of representatives from the Sanitary District, consulting firms, contractors, developers, public works personnel, and interested citizens. A wide range of disciplines and backgrounds can then contribute to the development of policy and this can add measureably to the success of a program.

Yet another way of attacking the problem of public participation is to develop public service announcements for broadcast by local television stations. The Huron River Watershed Council in Michigan achieved great success with this method. The Stormwater Runoff Program within the Water Planning Division of EPA is currently developing a slide show for use by areawide 208 agencies in explaining the problem of runoff pollution and what can be done to abate it.

Summary: The Preventive Approach

Because the preventive approach requires coordination at many levels, it will cause conflict. These institutional difficulties are clearly a drawback to the approach, but what other alternatives are there? Available evidence suggests that stormwater runoff will eventually dominate as a major source of water pollution. The reason is simply that as point source control meets the requirements of P.L. 92-500, urban runoff will be a remaining major problem. Also, urban areas do not remain static; they grow, and with this growth runoff increases.

A basic proposition advanced here is that existing institutions can be molded to fashion effective stormwater management programs. To accomplish this objective, however, the dilemma of stormwater management must be viewed from a certain perspective: controlling the sources of runoff pollution through their reduction and prevention. This perspective entails a family of abatement measures which are both physical and regulatory. In order to control stormwater runoff pollution these abatement measures must be applied systematically. To succeed at this task and to implement the management program requires an awareness of the institutional constraints which are present. These can be overcome through a careful consideration of who has jurisdiction over the sources of the pollution and what is required of these agencies and governments, both initially and on an on-going basis. Finally, the institutional constraints cannot be overcome without the awareness and education of those regulated.

6.3 A Brief History: Leon County, Florida

In 1973 Leon County, Florida passed three related ordinances: one directed to the protection of trees; the second for the control of erosion, sedimentation, and runoff; and the third aimed at the development of a landscape and open space plan. Each of these regulations influences stormwater runoff and demonstrates how stormwater management cannot stand alone as an individual objective. Rather, stormwater management must fit into a spectrum of environmental goals. In addition, the development of these ordinances indicates how stormwater management will require the support of many groups.

During the latter part of 1970, the onset of construction for Interstate 10 around the area of Lake Jackson and the construction of the Tallahassee Mall caused isolated instances of concern over the impact of polluted runoff into the Lake. At this point, the homeowners surrounding Lake Jackson organized themselves and demanded the protection of individual property and Lake Jackson. With this public expression of concern the County Commission recommended a study of the issue by various local and state agencies. This analysis was undertaken by the City Sanitation Department, Florida State University Department of Oceanography, the Tallahassee and State Departments of Health, and the State of Florida Department of Transportation. Indeed, the study verified the pollution problem and urged specific sediment controls as well as county-wide runoff control.

In consequence, the Department of Transportation and the developer set up sediment control structures on the two construction sites. The larger issue--that of county-wide runoff control--remained. Upon recommendation of the Tallahassee-Leon County Planning Department, a joint meeting of the Tallahassee City Commission and the Leon County Commission was held. It was decided that the County Commission would take the responsibility for the adoption and implementation of the environmental ordinances, but joint city-county funding was arranged. After a citizens' task force was appointed by the Planning Department, a series of workshops and public hearings were held. As a result, the Erosion, Sedimentation, and Runoff Ordinance was adopted.

The environmental package had support from many quarters. For example, the Environmental Development Committee of the Chamber of Commerce was instrumental in the passage of the tree protection ordinance. Moreover, at the workshops held prior to passage of the regulations, representatives of each of the following attended: Florida Fresh Water Fish and Game Commission; Florida State Oceanography Department; the American Institute of Architecture and many other groups.

What can be learned from the experinece of Leon County? First, it demonstrates that citizen awareness will create an incentive for local leaders and representatives to seek cooperation and that the problem of runoff, as part of larger environmental goals, is capable of gaining widespread support from the public-at-large. This was also the experience of the Huron River Watershed Council in Michigan. Through public service announcements, public meetings, and dissemination of educational materials the Council had a wide response from the electorate. In particular, the public service announcement proved an inexpensive yet effective method to gain citizen support for the Council's activities. Whatever the method chosen, stormwater management must be accompanied by public awareness.

Second, this example shows how the problem of runoff cuts across functional responsibilities. Here the State Department of Transportation and the Fresh Water Fish and Game Commission became involved in addition to the local agencies concerned with planning. Again, the detrimental effects of unregulated construction extend beyond the activity of the developer to involve state agencies such as the Department of Transportation.

Finally, the joint efforts of the county and the city prove that intergovernmental cooperation is possible. Because the problem transcended the city limits it was agreed to vest responsibility at the county level, but joint funding was arranged. In all, the issue of stormwater runoff was presented as one among a number of related issues--aesthetics, erosion control, noise reduction, water quality, recreational benefits, and aquatic life protection. The experience of Leon County, while not a model, proves that runoff control can be accomplished.

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2. Colorado, Hawaii, Kansas, North Dakota, Oklahoma, Rhode Island, Tennessee, and Utah.

3. For example, Connecticut General Statutes, Revised, Sections 25-69 to 25-83 (1958 and 1969 Supp.): state authorized to construct flood and erosion control works; Connecticut General Statutes, Revised, Sections 25-84 to 25-98 (1958): authorizes municipal flood and erosion control works; Hawaii Revised Statutes, Annotated, Sections 179-1 to 179-4 (1968): state agency given broad powers to study flooding, render technical assistance to communities, and let contracts for flood control works; Mississippi Constitution, Article 11, Sections 227-239: state authorized to maintain a levie system; Pennsylvania Statutes, Annotated, Title 32, Section 659 (1967): state agency may construct flood control works.

4. California, Hawaii, Indiana, Kansas, Michigan, Minnesota, New Jersey, North Dakota, Texas, Utah, Virginia, West Virginia, and Wisconsin.

5. Soil Erosion and Sedimentation Control Act, Act 347, Public Acts of 1972, as amended by Act 197, Public Acts of 1974, Michigan.

6. Memorandum from Owen C. Jansson, Executive Secretary for the Huron River Watershed Council, to John B. Cherny, Regional Director of the Bureau of Outdoor Recreation, dated July 22, 1974.

7. The constitutional implications of planned growth policies are beyond the scope of this chapter. The reader is directed to Chapter 5 of this manual and, in addition, to the many excellent legal analyses in the literature.

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9. DeKalb County, Georgia, *Code*, Chapter 6A.

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